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The Use of the Schmidt Telescope in Stellar Photometry*

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1. INTRODUCTION: It seems appropriate to discuss at this time the performance of Schmidt telescopes. Several large Schmidts have now been in operation for five to ten years and it seems likely that their number will at least be doubled in the next five years. The astronomers who have been privileged to operate for some time the existing Schmidt-type telescopes owe it to their colleagues who are just entering the field to give them a fair account of their experience in the operation of these new tools for astronomical research.

About ten years ago plans were made for the erection in Mexico and in the United States of three large Schmidt-type telescopes with correcting lens apertures of 24 to 26 inches, mirrors of 32 to 36 inches, and focal ratios of approximately 1 to 3.5. The principal Schmidt of considerable aperture that preceded these instruments is the 18-inch Schmidt of the Observatory on Palomar Mountain. The three Schmidts to which we have referred are the instrument at the Tonanzintla Observatory, the Burrell Telescope at the Warner and Swasey Observatory, and the Jewett Telescope at Harvard's Oak Ridge Station. These three instruments have fully justified the high hopes for their good performance of those who built them. The optics of the Tonanzintla and Harvard telescopes were figured by the Perkin-Elmer Corporation, those of the Burrell Telescope by the Warner and Swasey Company.

The war slowed down the effective putting into operation of these telescopes, but we have now had more than four years of uninterrupted experience with them. In this paper we are especially concerned with the use of the 24-33 inch Jewett-Schmidt telescope at Harvard Observatory's Oak Ridge Station as a tool for photographic-photometric research and our report deals only with this subject.

Astronomers have often, and with justification, sung the praises of the Schmidts as photographic recorders. No one who was educated in the tradition of the nineteen-twenties can fail to feel a tremendous thrill every time he or she inspects a photograph of ten-minutes exposure time that shows, with adequate scale and with perfect definition, over an area of the sky equal to 150 times that of the full moon, all stars to the sixteenth or seventeenth apparent magnitude, or even fainter. Such

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an instrument has obviously tremendous power for research on the structure of our Milky Way system, on the arrangement of faint galaxies, for studies of variable stars, and of many other topics.

This is not the occasion for further laudatory remarks. We consider it our task to report here about some of the difficulties that we have encountered. Some of the very features that make Schmidts most desirable, like sharpness of the stellar image and great speed, produce difficulties of various sorts and it is about these troublesome features that we should speak.

2. CURRENT PROGRAMS: The principal Schmidt programs of a photometric nature that have been carried out at the Oak Ridge Station and with which the authors have been associated fall largely into two groups. First come the basic photometric programs, in which plates taken in series with the region of the North Celestial Pole are used for the establishment of magnitude sequences in blue or red light through direct comparison with the North Polar Sequence. Next comes a group of star counting programs, in which photometric standard sequences are set up at the center of each plate by a process of step-wise transfer of a known near-by sequence (a Selected Area or the like).

The first group of projects—those involving direct photometric comparisons—consists principally of the three that follow:

1. *Gemini-Monoceros-Orion Project.* Photometric comparison plates in blue and red light were made for two centers on the Gemini-Monoceros-Orion project. The results have been described in a paper published in the July 1949 issue of the *Astrophysical Journal.* The exposure times for these comparison plates were quite short, chiefly between 30 seconds and 2 minutes. The blue and red magnitudes determined from these comparison plates were used to check comparable series plates previously taken with our 8-inch Ross and 16-inch Metcalf cameras.

2. *The C-Region Project.* Mrs. Simone Daro-Gossner, Mr. Joseph Gossner, and Bok have joined in the taking of plates on a project to check and extend the blue and red standard magnitude systems of four Harvard Standard C-Regions ($\delta = +15°$; C1-C4-C7-C10). Preliminary results for Region C7 have been published in *Astronomical Journal,* **53**, 209, 1948.

3. *Faint Cepheids in Cygnus.* Bok and Miss Olmsted have published in *Harvard Observatory Bulletin 919* (1949) preliminary results for a magnitude and color survey of the Baade-Oosterhoff Cepheids in Cygnus. Pairs of blue and red plates were taken on many good nights for the purpose of deriving the light curves of the variables and the curves showing their variation of color index with phase. In addition blue and red polar comparison plates were taken on most photometric nights; 103a-O emulsions were used for the photographic magnitudes, 103a-E emulsions (+ Wratten 25A filter) for the photo-red magnitudes.

One further current program that is closely related to this series of programs is worthy of mention. Mr. Stanley P. Wyatt, Jr., of Harvard has undertaken to test the feasibility of establishing photographically with the Jewett telescope a scale of magnitudes at a given center with the aid of a neutral half-filter. The half-filter—with a dimming constant of approximately 0.7 mag. in the darkened half—was provided for us through the courtesy of Baird Associates. The filter is a remarkably good one; corrections for lack of neutrality amount to 0.02 mag. at the most and laboratory tests show that there is almost perfect uniformity of transmission over the filter-half. The experimental work by Wyatt is for Harvard Standard Regions C1, C4, and C10.

The most extensive star count programs that are either completed or well advanced are the three that follow:

1. *Gemini-Monoceros-Orion Project.* The plates for this program (60-75 minute exposures on 103a-O emulsions) have been taken by Bok and the counting and transfer of sequences is in the hands of Father James K. Connolly of Holy Cross College. There are twenty-five centers two to three degrees distant from each other. It has been standard practice in the Harvard Observatory star count projects not to push to the faintest visible limit; Father Connolly is counting complete to $m = 17.4$ on the average.

2. *Cygnus Project.* Bok and Father Roger Leclaire—formerly at Georgetown and now of the Vatican Observatory—took most of the plates (60 minute exposures on Cramer Hi-Speed emulsions) for a series of centers in Cygnus in the section near and between Selected Areas 39, 40, and 41 at $\delta = +45°$. These plates were made some years ago with a silvered mirror; the Jewett mirror has been aluminized since 1946.

3. *The Intermediate Latitude Project.* During a stay of several months at Harvard, Dr. Freeman D. Miller of the University of Michigan took a series of plates for a band of the sky at galactic latitude $-30°$; the exposures were uniformly of 30 minutes duration.

Smaller star count programs have been undertaken for several sections of the Milky Way and while we shall not refer to these, we may point out that the available results are in substantial agreement with those of the other projects, at least as far as experience with accidental and systematic errors, freedom from distance correction, and experience with the step-wise transfer of sequences are concerned.

In the survey that follows we shall draw extensively upon the results of the work of the investigators named above who have made use in their photometric researches of photographs made with the Jewett telescope. We thank all of them for their assistance in providing us with unpublished results of their investigations.

3. Accidental and Systematic Errors: To date all measurements at Harvard have been made with the aid of so-called "fly spankers," reference scales of series of images with graded short exposures for

relatively bright stars. Our experience shows that there is little to be gained by measurement with a Schilt photometer. We are aware of the claimed advantages of the Siedentopff variable aperture photometer, but we have had no experience with its applicability to our programs.

The short-exposure polar comparison plates in blue and red for the Gemini-Monoceros-Orion project gave us the first indication of a limitation of the Schmidt for work of this sort. We reproduce here again two tables from our article in the July, 1949, issue of the *Astrophysical Journal*. They show that, to reach the same accuracy with regard to accidental errors, we need two to three times as many Schmidt comparisons as for the 8-inch Ross (IR) or the 16-inch Metcalf (MC) refractors.

TABLE 1

	Blue			Red		
	IR	MC	J	IR	MC	J
No. of plates	5	4	10	5	4	5
Av. p.e./meas.	±0.12	±0.08	±0.16	±0.10	±0.05	±0.17
Ave. p.e./star	±0.05	±0.04	±0.05	±0.05	±0.02	±0.07
Syst. fr. mean	+0.07	−0.07	0.00	−0.01	−0.06	+0.08

TABLE 2

	Blue			Red		
	IR	MC	J	IR	MC	J
No. of plates	4	4	10	5	4	7
Av. p.e./meas.	±0.09	±0.04	±0.13	±0.12	±0.06	±0.16
Ave. p.e./star	±0.04	±0.02	±0.04	±0.05	±0.03	±0.07
Syst. fr. mean	+0.06	−0.01	−0.05	+0.04	−0.06	+0.02

We mention three possible causes of trouble:

1. The very excellence of the Schmidt images makes them highly susceptible to the effects of changes in the figure of the mirror. Even with a most carefully-mounted mirror, slight variations in its figure (depending on declination and hour angle) will lead to a slightly different appearance of the images for the polar plate and for the field plate with which it is to be compared. The not-so-perfect optics of the older photographic refractors produce at all times slightly washed-out images, which are identical for all positions of the telescope. For a Schmidt, the out-of-focus images have of course central holes (plate-holder shadows) in them and out-of-focus Schmidt images are therefore not usable for photometric purposes.

2. Seeing is another variable factor. The size of the seeing image is comparable under good conditions to the size of the instrumental image in the Jewett telescope. The size of the seeing image depends considerably on the altitude of the region and sometimes also markedly on the azimuth.

3. Variable sky brightness is a third source of trouble. Even for quite short exposure times the sky-fog becomes bothersome and differences in sky-fog for plates of the same exposure time in different parts of the sky can be quite marked. The background brightness of

the Milky Way often brings up the fog for centers at low galactic latitudes, whereas in high latitudes the fog may be much less for the same exposure time. But more troublesome than the general galactic background are the effects of the permanent aurora—not to mention the effects of auroral displays! On many nights at the Oak Ridge Station the sky toward the north is perceptibly brighter than toward the south. This naturally leads to differential fog effects, which are presumably always present for longer exposures.

The results of the Gemini-Monoceros-Orion project are confirmed by comparative measurements of Jewett and MC plates for the Cepheid center in Cygnus. The probable error for one single measure of a magnitude on one single plate, as derived from many polar comparisons (30 comparisons altogether) in blue and red light, has an average value equal to ± 0.11 mag. It would seem from this that it would take about 13 comparisons to reduce the probable error of a derived mean magnitude to ± 0.03. Comparable values for the MC are: ± 0.06 for the probable error of a derived magnitude from measurement of one image on one plate and ± 0.03 for the mean from four plates.

The above comparison should, however, not be taken at its face value, for in photographic photometry systematic errors are fully as troublesome as accidental errors. The number of comparisons required to check on the systematic errors is certainly not less than ten and should preferably be twice as large. Generally speaking, there is always a need for so many "zero-point" plates to check systematic errors that a sufficient number of measures are made to reduce accidental errors to reasonable amounts.

The results of Tables 1 and 2 seemed rather re-assuring as far as systematic errors are concerned. Some recent results for the Cygnus field, however, have not confirmed us in our optimism with regard to systematic errors. Nassau and MacRae (see July, 1949, issue of the *Astrophysical Journal*) have determined magnitudes in field LF3b, which is quite close to our Cygnus center. Dr. Nassau kindly sent us the blue and red magnitudes for a standard sequence of his center. Intercomparison between our measures and Nassau's sequence has revealed the presence of some rather disturbing systematic differences.

The Nassau sequence depended upon direct polar comparisons (with an equal number of comparisons made with the telescope *E* and *W* of the pier) and upon comparisons with the near-by Selected Area 39. The Harvard material consisted of 11 direct polar comparisons on blue-sensitive plates, and ten on red-sensitive plates. The rather disturbing results for photographic magnitudes are shown in Table 3. We should mention that distance correction has been applied (see section 4) and that there was no need to apply a correction for color equation.

TABLE 3

Star No.	Jewett ptg. mag.	Nassau ptg. mag.	Nassau—J
11	12.01	11.72	—.29
12	12.32	12.09	—.23
13	12.79	12.46	—.33
14	13.10	12.77	—.33
15	13.75	13.44	—.31
16	13.84	13.74	—.10
17	13.97	13.76	—.21
18	14.37	14.16	—.21
19	14.55	14.48	—.07
20	15.05	14.89	—.16
21	15.27	15.18	—.09
22	15.27	15.22	—.05
23	15.60	15.61	+.01
24	16.18	16.06	—.12

The mean systematic difference Nassau minus Jewett is -0.18 mag. We note that the differences are largest for $m_{ptg} = 12 - 14$ and that there is generally much better agreement for magnitudes 14—16. A comparison was also made between the Nassau magnitudes and the magnitudes of his sequence derived from polar comparisons with the MC camera (4 comparisons per star on the average), with a resulting mean systematic difference of -0.10 mag. At Oak Ridge we have taken every precaution and the Warner and Swasey astronomers have similarly been very careful in the setting up of their basic sequence. And yet we are faced with an unexplained systematic difference of the order of 0.15 mag. between the two derived final sequences.

It had been suggested that an uneven distribution of exposures with the telescope *E* and *W* of the pier may have been a source of error. Mr. and Mrs. Gossner have provided us with what appears to be conclusive evidence that this is not at the bottom of our difficulties. For Harvard Standard Region C7 the mean photographic magnitude with Tel *E* of the pier (15 plates) minus the corresponding mean for Tel *W* of the pier (16 plates) is $+0.07$ mag. with a probable error of ± 0.03 mag.

We have also available somewhat less complete comparisons between the Nassau and Jewett magnitudes in the photo-red range. Here the mean difference Nassau minus Jewett $= +0.25$ mag., but there are only two stars fainter than $m_{pr} = 13$ in the Nassau sequence. The derived Jewett magnitudes in the red are in excellent agreement with the mean from 5 MC comparisons, the systematic difference being equal to: MC minus Jewett $= -0.04$ mag. (± 0.03).

While the above results are preliminary, and will require further investigation when the Cygnus center becomes again accessible, we may speculate tentatively about the cause of these systematic differences. Because of the large number of comparisons, with each telescope in a great variety of positions, it seems unlikely that seeing errors or errors arising from differences in figure of the mirrors can explain the discrepancies. Systematic fogging effects and differential extinction de-

pending on azimuth, either at the Oak Ridge Station or at the Warner and Swasey Observatory, seem to be the most likely reasons for our difficulties. It would be most desirable to have this particular sequence checked independently at some other observatory or by photo-electric observations.

Before we close this section, we wish to make two further comments, one cheerful, the other not so cheerful.

First, Miss Olmsted has made a careful study of the light curves of the Cepheid variables in Cygnus. The 10-minute Jewett plates proved to be fully the equal of 45-minute plates with the MC camera. The effectiveness of the Schmidt in research on variable stars cannot be questioned.

Second, Mr. Wyatt has finished reductions of some plates photographed through the neutral half-filter and centered on the North Celestial Pole. Each plate has two exposures of five minutes, one with the polar sequence stars photographed through the dark half of the filter, the other with the filter reversed and the center shifted slightly. The total fog is thus about the same on each half of the plate, but the "faint" polar images are post-exposed to the full sky brightness whereas the "bright" images are pre-exposed only to filtered sky brightness. The reductions require the establishment of a second sequence on the opposite side of the filter-line, but here the "faint" images are pre-fogged and the "bright" ones are post-fogged. In each case the derived half-filter "constant" ranges all the way from 0.57 to 0.73 mag. for different plates and exposures! Wyatt's analysis of the available material suggests that a slight field asymmetry may be the principal source of error. His results yield a striking example of how slight asymmetry of field in the instrument and differential pre- and post-fogging due to sky background can affect photographic photometry with the Schmidt. The neutral half-filter—which works well with telescopes of large focal ratio —does not promise to serve efficiently with the Jewett camera. For basic determinations of magnitude scales we had apparently better turn to the photo-electric photometer.

4. Distance Correction: Ideally the aperture of the mirror for a Schmidt should be 50% greater than that of the corrector lens. Otherwise vignetting produces a considerable "distance correction" in magnitude work. For the Jewett telescope the mirror aperture is three inches short of the desired value.

Father Leclaire has made a careful study of the distance correction of the Jewett telescope. In his calculations he has rightly assumed that, for a well-constructed Schmidt, there are no appreciable optical defects and, further, that the curvature of the back of the plate holder equals the true curvature of the field. There is further no excuse for appreciable errors in squaring on of the plate holder with respect to the primary mirror and we may ignore this at first as a cause for (asymmetrical) distance correction.

Theoretically there remain then two possible causes for a difference in the measured brightness of the images of two stars of the same apparent magnitude, one near the center of the field, the other toward the edge. The first of these is straight vignetting; in other words, the star image near the edge of the field "sees" illuminated only one section of the mirror. The second is the effect of a *variation* with the distance from the center of the field in the shadow-effect produced by the plate holder, its carrying device and the fins that hold it in place, and the guiding apparatus. Leclaire's calculations indicate that the second cause has little effect and that the actual distance correction arises principally from vignetting; it still remains to be seen to what extent this conclusion may have to be modified in view of Wyatt's results of the preceding section.

Leclaire's calculated values for the distance correction that must be applied if a measured magnitude for a star near the edge of the plate is to be reduced to the value it would have had at the center, are given in the second column of Table 4. In his calculations Leclaire assumed that the corrector lens produces a widening of about one inch in the bundle of rays that enter the telescope; this seems to be too large a value for a corrector lens as weak as that of a Schmidt. Hence we may consider Leclaire's calculated values as upper limits. The change in correction does not amount to more than 0.04 mag. at the most.

TABLE 4

Distance in mm	Δm computed	Δm observed
50	—0.01	....
60	— .04	0.00
70	— .09	— .11
80	— .15	— .15
90	— .21	— .23
100	— .28	— .30
110	— .36	— .39

Leclaire checked his computed values for the distance corrections by a series of multiple exposure plates, each containing as many as five short exposures on the North Celestial Pole centered 1° apart. These plates gave no indication for the need of the application of any distance correction to a distance of 60 mm from the center. The derived distance corrections for greater distances from the center are in the third column of Table 4. No dependence of distance correction upon position angle appeared in his results.

The first study of the effect of distance correction for the Jewett telescope was made by Dr. Freeman D. Miller on the basis of a group of plates taken for the purpose by Bok and Dr. Elsa van Dien. Three of the seven plates had Selected Area 37 at the center, the four remaining ones had it near one of the corners. Every plate had five exposures of equal length taken at slightly different focal settings. Miller found that the mean difference between "best focus" and "poorest usable

focus" was 0.003 inches. He determined the distance correction to be applied at an average distance of 85 mm from the center. The correction at that distance is about equal to — 0.10 mag., somewhat smaller than Leclaire's value, but in line with the value computed without the effect of the enlarged bundle of rays. Surprisingly, but rather happily, the amount of the correction is not markedly dependent on the exact focus setting. Miller's results show further that an error of 0.003 inches in the exact squaring on of the plate holder produces corresponding errors of less than 0.10 mag. in the derived magnitudes.

Quite recently Dr. Miller has sent us the results of an independent star count check on the effect of distance correction. His results depend on counts for 100,000 stars on five Jewett plates at galactic latitude —30°. He counted an area of 16 x16 cm on each plate, the full size of the plate being 20 x 20 cm. The results are shown in Table 5. The first column gives the four limits to which counts were complete and the second column gives the amount in magnitudes of that particular limit above the plate limit. The third column gives the average value of the difference between the counted value of log N for an inner area of 12 x 12 cm and the counted value of log N for the remaining outer strip 2 cm wide; the log N's were first reduced to equal areas of the sky. A plus sign indicates an excess of stars to the limit within the inner area. These results show conclusively that the systematic differences converted to magnitudes are equal to 0.04 mag. at the worst.

TABLE 5

Limit	Δm	$\overline{\Delta \log N}$	$\overline{\lvert \Delta \log N \rvert}$
1	2.9 mag.	+0.009	0.022
2	1.8	+ .009	.022
3	0.9	+ .008	.013
4	0.0	+ .011	.014

The last column of Table 5 shows the mean absolute values of Δ log N. The scatter from plate to plate is considerable compared to the small systematic effect. The worst single discrepancy occurs for the brightest limit on one plate, where the difference Δ log N is equal to + 0.05, which corresponds approximately to 0.17 mag.

If, as seems advisable, we confine ourselves to a circle with a radius of 9 cm on the plate, the distance correction in the outermost part of the area will at most be 0.2 mag., and we may ignore distance correction completely to a distance of 6 cm from the plate center.

5. Transfer of Sequences: A photograph with a Schmidt telescope that lacks a good central sequence is of little use for purposes of galactic analysis. The available sequences in the Selected Areas provide one—in the northern hemisphere at least—with a good sequence not more than ten degrees away from any desired center. We have been quite successful in the transfer of sequences through a step-wise procedure, using a series of plates connecting the desired center and the Selected Area center, with successive plates in the series having their

centers preferably two or three—and certainly not more than four—degrees apart.

As an extreme test of this procedure we quote the following result communicated to us by Father Connolly. This test involves a string of six plates connecting S.A. 74 (at $\delta = +15°$) and S.A. 98 (at $\delta = 0°$). The plates were taken over a considerable interval of time on good nights, but generally on nights not suitable for accurate comparison photometry. The results are in Table 6, where the first column gives the photographic magnitude of a sequence star in S.A. 74 (according to the Mount Wilson Catalogue of Selected Areas) and the second column the magnitude of the same star derived by a step-wise transfer from S.A. 98 as a standard.

TABLE 6

S.A. 74	Transferred from S.A. 98	Δm	S.A. 74	Transferred from S.A. 98	Δm
14.90	14.74	+.16	14.56	14.66	−.10
16.74	16.74	.00	15.83	15.80	+.03
15.37	15.28	+.11	15.26	15.34	−.08
14.66	14.50	+.16	14.77	14.92	−.15
15.50	15.50	.00	16.26	16.05	+.21
14.09	14.11	−.02	16.53	16.47	+.06
14.18	14.36	−.18	14.36	14.36	.00
16.12	15.95	+.17	15.02	14.94	+.08
15.94	15.88	+.06			

The systematic difference between the two series of magnitudes amounts to + 0.02 mag., and is of course negligible. The dispersion in the residuals amounts to ± 0.12 mag.

To check further on accumulation of errors a transfer by two routes was made from S.A. 74 to a near-by center. One route involved only one single transfer of a sequence, whereas in the second route four separate transfers were required. Father Connolly reports no evidence for the presence of systematic errors. The differences between the magnitudes derived from the long and the short paths give a dispersion of ± 0.14 mag.

Father Leclaire reports similar good results for a step-wise transfer of a sequence from S.A. 40 to S.A. 39 in Cygnus. Here six intermediate sequences were required to complete the series. Again no appreciable systematic error was found to be present and the dispersion in the values of Δm proved to be equal to ± 0.17 mag., in substantial agreement with the results for the Gemini-Monoceros-Orion fields.

We conclude on the basis of the above evidence that the transfer of standard sequences by the step-wise method is a perfectly safe procedure for the establishment of a magnitude sequence at the center of any Schmidt plate, provided careful attention is paid to distance correction.

6. Conclusions: The superiority of the Schmidt-type telescope as a photographic recorder stands unchallenged. The perfection and uniform quality of images over a large field continue to make it a most

desirable instrument for galactic research. The great speed of these telescopes places them in a class by themselves.

These same qualities of undisputed excellence produce, however, certain rather disturbing errors in photometry with a Schmidt. Our experience at Harvard has been that accidental errors of magnitudes measured on Schmidt plates are markedly greater than those obtained in work with less perfect telescopes. Slight differences in image shape depending on the position of the telescope, coupled with effects produced by variations from region to region in seeing and in brightness of the sky background, make it necessary to use approximately twice as many Schmidt comparisons as would be necessary with the common types of photographic refractors. Greater precautions must be taken to avoid the introduction of systematic errors in the system of magnitudes.

The smallness of necessary corrections to magnitudes depending on the distance from the center of the field is confirmed by numerous tests. The comparative freedom from "distance correction" is the greatest photometric asset of the Schmidts apart from their faint limiting magnitudes. It is because of this uniformity over the field that one can transfer standard sequences of magnitudes by a step-wise procedure from one center to another as much as ten degrees distant without introducing either perceptible systematic errors or increasing the sizes of the accidental errors by more than may be expected from the effects of purely random errors of measurement.

HARVARD COLLEGE OBSERVATORY.

The Nininger Collection of Meteorites*

By H. H. NININGER

INTRODUCTION

The custom of publishing catalogs of large collections of meteorites has contributed greatly to the science of meteoritics. Without such sources as the catalogs of Buchner, Brezina, Meunier, Wadsworth, Wölfing, Cohen, Fletcher, Farrington, Prior, Ward, Merrill, Foote, Hodge-Smith, Coulson, and others, workers in meteoritics would indeed find themselves at a serious disadvantage.

It has been the general practice to include more or less of descriptive material in addition to the mere listing of identification data. Thus these catalogs actually serve as source books of information on very many phases of the study of meteorites.

The present volume as presented is, in some respects, an innovation. While it contains considerable descriptive material in addition to identi-

*It is to be noted that we are printing here only the introductory part of "The Nininger Collection of Meteorites." The complete volume is now in the hands of the publisher. Further information concerning it may be obtained by directing an inquiry to Dr. H. H. Nininger, American Meteorite Museum, Box 1171, Winslow, Arizona, U.S.A. EDITOR.

fication data, its main objective is to bring up to date the concrete results of a program of search for meteorites that is now in its twenty-seventh year.

In some ways, the meteorite collection of H. H. and Addie D. Nininger differs from all other collections: It has grown directly out of an idea that was born in the winter of 1923-24. A search for meteorites from the great fireball of November 9, 1923, had fruited in the discovery of two meteorites, neither of which bore any relation to the fall sought, except as to location. Both were old, one an aerolite and the other an oxidized siderite, and they were found only about twelve miles apart.

The fact that the discoverer of these two meteorites had not previously met with a meteorite in the field, and had not even so much as met any scientist who had ever, to his knowledge, discovered a meteorite, seemed to be significant. He reasoned that if one brief search (admittedly a rather intensive one) could yield two meteorites in a small area, designated as the probable location of a third fall, then certainly meteorites must be more abundant on the earth than was generally believed.

Certainty in soundness of the theory grew. Some six years of further testing by planned search indicated its truth. By every available means the campaign was prosecuted, and the collection listed in the present catalog is the concrete result. While many of the items now prominent in it were not discovered by the search described, or by anyone connected with the program, they all, directly or indirectly, were assembled as a result of it.

Exchange of specimens has been widely indulged in. This policy was dictated in fairness to various institutions and collectors who sought to enlarge their collections but who did not engage in any program of exploring for meteorites. It is at once evident that only by this means could we obtain representatives of the older discoveries, many of which had special significance for the student of meteorites.

Always the objective of research was kept uppermost in our program. Therefore, the collection could be of value in proportion as it was representative. Also, where new discoveries were being made constantly, the question of identity is ever before the researcher and for comparison purposes a large and representative collection becomes of prime importance.

The search which in its beginning had been viewed so skeptically grew more and more successful until, in the year 1937, resulting new discoveries totaled thirty-one—a greater number than had been recorded throughout the world in any three-year period prior to the beginning of our search.

The search was successful not merely in the number of finds, but also in another very important respect, which is now reflected in the collection. Its content of stony as compared with metallic meteorites is

more nearly consistent with the prevalence of stone in the increment from space than is true in any of the other great collections. Also, its representation of unwitnessed falls of stony meteorites reflects the geological importance of meteoritics as does no other collection.

At the inception of the search, metallic meteorites were far more numerous in the records of North American finds than were stony meteorites. Farrington's catalog, published in 1909, listed 161 as against seventy-six stones. Of the latter, fifty-six were witnessed falls, leaving only twenty stony meteorites of unwitnessed fall for the entire continent of North America. On the other hand, only three of the irons had been seen to fall.[1]

The striking inconsistency of these figures had occasioned considerable speculation. Merrill went so far as to propose that there may have been a change in the relative basicity of the general meteorite population that was being encountered by the earth in his time as contrasted with that met centuries earlier. Farrington recognized the discrepancy, but was inclined to base all considerations of the problem of meteorite distribution on four factors, *"density of population, character of population, climate, and character of soil."*[2] He pointed out that a map of the known distribution of meteorites conformed almost exactly with that of the Caucasian race.[3] But he also noted that the chief concentration of meteorite finds had been in, or near, areas of high elevation, and believed there was "little doubt that some force tends to bring about their concentration" in some areas.[4] He suggested a magnetic force, or that high elevations favored the interception of meteorites as they arrived. He even applied these principles to the Kansas concentration which, while not exactly *in* a greatly elevated region, did lie "within a few hundred miles of the mountain masses which culminate in Pike's Peak."[5] Kansas at that time was credited with fifteen meteorites.

We were unable to agree with Farrington that the "degree of intelligence" was a factor. It was our conviction that a very particular kind of knowledge was responsible for the finds which were recorded in Farrington's own book[6] and the "degree of civilization" had little to do with the matter. Otherwise, why should the hill population of the Appalachian states report an outstanding number of finds against none in several New England states?

We were never able to admit any possibility of preference for landing in any particular type of topography or any geographical location with the possible exception of latitude. We conducted our search on the assumption that all parts of the equatorial and temperate zones at least,

[1] O. C. Farrington, *Catalogue of Meteorites of North America*. National Academy of Sciences, Memoirs, Vol. 13, 1915, p. 11.
[2] *Ibid.*, p. 13.
[3] *Popular Science Monthly*, 1904, p. 352.
[4] *Ibid.*, p. 11.
[5] Farrington, *Catalogue of Meteorites of North America*, p. 12.
[6] *Ibid.*

had and were receiving an equitable contribution from space. We recognized that aridity favored longer preservation as against moist climate, that heavy growth of vegetation rendered finds more difficult, that rocky terrains made recognition less likely. Calculating the number of acres a man could look over in a day (two to twelve acres), we decided that purposeful searching for meteorites would never prove fruitful, except in areas where a fall was known to have taken place recently.

In view of all of these factors and the observed fact that less than one person in a thousand, including educators and laymen in one general group (we found little difference due to education), had the information necessary for the recognition of meteorites, we decided that a successful search for meteorites could be carried on through a program of lectures in schools serving agricultural communities. All lectures were to be illustrated with specimens. We favored areas of light rainfall but where cultivation was generally practiced. We chose areas not too badly infested with rocks and where the population was fairly dense. We placed knowledge of the appearance and importance of meteorites above all other factors. Instruction on this last point was emphasized by a standing offer to buy any finds.

Without any known precedent we developed two distinct procedures —one having to do with meteorites of unwitnessed fall as described above, and the other with the tracing of fireballs which were considered good prospects for the deposition of meteorites. The latter proved much less fruitful, but it was practiced with equal diligence because of its scientific importance. Our over-all objective from the first was to gain an intelligent estimate of the nature and magnitude of the increment from space.

Neither in person nor by reading were we able to come into contact with any scientist who had ever conducted a survey that had resulted in the discovery of a meteorite from a witnessed fall. All such falls as had been collected had been recovered by workmen or other laymen who chanced to see the landing or who, out of curiosity, had reported a peculiar stone. All scientists whose advice was sought discouraged us. It was considered a hopeless task. Nevertheless, we were determined to try it. Even though our first effort had failed to recover the arrival sought, we were convinced that the method was right and were later able to justify the conviction.

Several attitudes and techniques of approach contributed to the success of this method. (1) The immediate recognition that precision data would always be unobtainable and that this lack must be compensated for by a large number of widely scattered observations. (2) Reports by mail could be used only for certain general information and would be mainly useful in locating the witnesses to be interviewed. (3) Only on-the-spot interviews would be of use. (4) Certain facts could be more reliably obtained from areas remote (100 to 200 miles) from the fall, while others must be obtained in close proximity to the landing

(within a twenty-five mile radius). (5) The psychological problem of evaluating witness would be of prime importance. (6) Finally, after designating the area to be searched, if it is a populated area, the search could best be carried on by using the educational method described above, except that in this case the characteristics of fresh rather than weathered meteorites should be stressed.

There was another factor, an important one, which American industry contributed. Twenty years earlier, such surveys could not have been carried out with sufficient dispatch (and in some surveys time is of the essence) for lack of transportation and communication facilities. The time was ripe for a career of fireball chasing.

The search for unwitnessed falls, on the other hand, could have been more fruitful a generation earlier when all cultivation was done by means of horse-drawn implements. Modern mechanized farm methods do not favor the finding of meteorites. Our greatest success was had in areas where men still lived who had broken up the native sod with "walking plows." They remembered where they had encountered a heavy rock that crumpled the plow point and sometimes were able to point out the present location of the stone.

Productive as the search became, we were never able to find a sponsor for it among educational or research institutions. We were forced to finance it by the sale of specimens and by charging for lectures. The collection here cataloged is probably not larger in number of specimens than our sales material of the past twenty-six years together with the sales stock now on hands would aggregate. This commercial phase of our program was always distasteful to us but it was not without its scientific value. The principal outlets for specimens were the great museums and a few of the large universities. In order to supply them it was necessary to know what they already had. Therefore, no opportunity was missed for studying their collections and catalogs.

From the first, we set for ourselves the highest standard of accuracy. Cataloguing of the Nininger Collection has always been a time-consuming aspect of the project. Nothing took precedence over the correct labeling and recording of specimens.

One of the ways in which the selling of specimens has promoted the science of meteoritics has been the stimulation of a more thorough search for individuals of the various falls. Since we were all the time building our own collection, duplicates must constitute our sales material. Therefore, the greater the number of duplicates, the better.

The Ness County meteorite is a case in point. After the books had been closed on this fall for more than twenty years, some forty stones were found in the hands of farmers of that region; a few museums had good representations of this fall and had no wish to make further purchases. Two very fine specimens of the Brenham pallasite had been held by Mrs. Kimberly for years for want of a market. After we bought them, others began showing up on the farms in that commun-

ity and it was our prosecution of that search which revealed the Haviland crater. It also led to the discovery of the little Haviland aerolite.

Our work on the Brenham fall, which followed a lapse of activity for nearly twenty years, finally yielded nearly as much additional material as the total that already had been credited to this fall. And it was another aspect of our forced commercialism which later resulted in the magnificent instrumental search carried on by H. O. Stockwell that added another 3,000 pounds to the record of the Brenham pallasite.

Plainview is another illustration. The U. S. National Museum purchased and distributed specimens until a total of twelve had been recorded. The last two Dr. Merrill declined to buy and consequently interest in collecting ceased in the community. The U. S. National Museum closed its records on this fall in 1918, crediting it with a dozen stones and a total weight of sixty-eight pounds.

After a lapse of fifteen years, and following assurance by Dr. Merrill that there was nothing more to be learned from this meteorite, we began a search of the area in 1933. The story of this search, which is still under way, will be a long one; it is enough to say here that the expenditure of something over $3,000 has to date placed on record more than 900 stones of the Plainview fall and has brought to light five other falls which overlap the area.

Because of their very typical appearance and because they have been the least expensive to collect, these Plainview stones have served science in another way. They could be supplied to beginning collectors at a lower price than other meteorites and so have helped in a very real way to spread information as to the nature of meteorites and to create interest in many communities. Thus we have been able to make our researches on this fall self-supporting.

The Beardsley fall, on the other hand, was first reported to a private collector who never "commercialized" on his collecting. After securing two small stones he informed us that he was through, so with his permission we went into the area and recovered more than sixty stones, increasing the recorded weight by more than one thousand per cent.

The Garnett meteorite with its copper inclusion is an illustration of another way in which commercial handling of meteorites may sometimes prove to be of value to science. When this ten-pound stone reached the laboratory it was one of the most unimportant looking specimens we had ever discovered. It appeared to be of no particular use as a study specimen since the fusion crust was weathered away. And a small polished face revealed that it was a very common variety of chondrite. It was catalogued and stored as being undesirable for exhibition purposes. Financial pressure, as was often the case, forced us to turn from research to filling orders. We looked over the stock and Garnett was selected for the cutting of six slices of a typical chondrite. During the process of polishing those six slices the lump of metallic copper was

revealed which is still by far the largest copper inclusion ever found in a meteorite.

The composite character of the deposit of meteorites around Barringer crater was also discovered as a direct result of filling orders. We found it more economical to cut a number of these small irons at the same time. In etching these many sections we noticed that a few of them showed a pattern definitely distinct from the normal range of Widmanstätten structure that is characteristic of the many Canyon Diablo irons that we had previously handled. Subsequently, at least two more strange patterns were discovered, a study of which revealed that they were distinct from the well-known Canyon Diablo phase of this meteorite deposit. The unusually large carbonado inclusion in a Canyon Diablo iron described by the U. S. National Museum was also discovered while we were preparing cabinet specimens for sale to collectors. At least twenty-four specimens have been found to contain diamonds among the more than 300 sections of Canyon Diablo irons prepared in our laboratory.

The Plainview fall had been described mineralogically in two papers by George P. Merrill in 1917 and 1918.[7] But in the process of preparing a number of slices from various individuals of this fall three very distinctive mineralogical characteristics were revealed in the otherwise typical Plainview stones. These features are not to be confused with the overlapping falls mentioned earlier in this introduction. These new features are all well exhibited in the Nininger Collection. Complementary (this term is applied to cases where two complementary encrusted individuals of a fall have facets which, though irregular in form, fit together) individuals of a shower are very rare and significant. Only a few are known among all of the collections of the world. A perfect pair of these was recovered in the course of our survey.

While preparing a large assortment of etched sections cut from the collections of irons purchased in the village of Xiquipilco, Mexico, in 1929, our laboratory revealed not only a distinctive Widmanstätten figure evidently belonging to a different meteorite but also the striking case of triple orientation of octahedral structure shown in Pl. III, Fig. 8, of the complete volume.

Many other examples could be cited but these are sufficient to indicate the manner in which we have managed to make a necessary degree of commercialization serve the science of meteoritics.

It was Dr. Joseph P. Connolly, President of the South Dakota School of Mines, who made the public announcement in 1934 that our great contribution to meteoritics had been in changing the emphasis on meteorites, stressing the importance of quantity and geological significance rather than chemical composition alone. Incidentally, it was after the Nininger lectures within the state of South Dakota in that

[7] *Proceedings of U. S. National Museum*, Washington, 1917, Vol. 52, p. 419; and 1918, Vol. 54, p. 503.

year that there turned up the first South Dakota meteorite since 1892. This Bear Lodge iron had been known for some time but not to scientists. The Bennett County, Cavour, and Harding County discoveries followed additional lectures in quick succession.

The effectiveness of the program was demonstrated also in several other states. Our base of operations was moved to Denver in 1930. From this location on the edge of the great plains we selected, from time to time, areas where our efforts were to be concentrated for given periods. The introductory campaign was carried out, after which we would withdraw to another area while the seed sown was given time to germinate. Sooner or later we would return, either because a find had been made or because we felt the need for additional stimulus was indicated. We consistently clung to the belief that meteorites were available in practically all communities.

Up to 1931, nine meteorites (all irons but one) had been recorded for Nebraska. Dr. Barbour of the State University Museum was approached on the matter of a field search for meteorites. He invited us to exercise a free hand and good-naturedly opined that if there were any meteorites present the university field parties should have found them.

We carried out several limited campaigns within the state during the next twelve years and discovered twenty different falls, only one of which was witnessed. In contrast with the finds previous to 1931, all but one of these were stony meteorites.

Before 1933, only three meteorites were known in that part of Texas lying north of the thirty-third parallel. That year we began a campaign in the Texas Panhandle. By 1946 we had located twenty-six additional falls, all unwitnessed.

One lone meteorite had been recorded for the great state of Wyoming previous to 1933. That year we began working in the southeastern part of the state. By 1939 we had listed eight different discoveries, all of which were directly traceable to our work, and one witnessed fall which we also had the good fortune to record.

The Colorado map of 1930 showed twelve meteorites, all siderites but one, which was a witnessed fall. By 1940 we were able to add twenty-six stony meteorites and two pallasites. And by 1949 two more irons were added.

Kansas, of course, was the base for most of our early operations and we continued to work there intermittently. It was only natural that more finds were made there than in any other state. Fifteen meteorites had been recorded for Kansas by 1906, and only one more was added to the records before 1923 when our effort was begun. By 1949 we had added thirty-seven to the list and several more were traceable to our efforts even though they were recorded by others.

That this plan is applicable only to the cultivated plains states is not a justified conclusion, for to a limited extent the same method has been

used successfully in Missouri, Minnesota, Arizona, Canada, and among the lava hills of northeast New Mexico.

In addition to demonstrating a successful method of meteorite collecting, the results of this program have opened up several new phases of meteoritical research, some of which have important geological, mineralogical, and astronomical implications. But the discussion of these phases does not properly belong in this volume.

Beginning in 1924 with the discovery of the oxidized siderite of Coldwater, Kansas, we became more and more interested in the terrestrial careers of meteorites. According to all logical considerations, traces of meteorites should be found in at least some of the various geological formations but they had never been identified. We therefore sought to find a method of tracing meteorites back into the older formations. It has always been evident to us that meteoritics is at least as much a geological as it is an astronomical science. And although geologists have been slower than astronomers to recognize the obligations and opportunities that meteorites bring to their science, yet we consider the possibilities in that field fully as great as in astronomy.

The Nininger Collection, therefore, includes a cabinet devoted to meteorites in various stages of weathering. This department grows more interesting and meaningful each year, and now comprises several hundred specimens from twelve different falls, each of which presents some light on the question of what happens to meteorites after they take up residence on a weather-troubled planet.

Notable Specimens

The Nininger Collection, besides being a product of a continuous program of field search, also reflects a wide range of interest in other research problems. Its founder had long maintained a keen interest in the conflict between arriving meteorites and the atmosphere through which they plunge to the earth. Consequently, an effort has been made to secure specimens which record that conflict in the most graphic manner. Specimens which are especially outstanding in this respect are the *oriented* specimens of Bruno, Sioux County, Pasamonte, Holbrook, Plainview, Estherville, Glorietta, Whitman, Henbury, Wellman, St. Ann, Johnstown, and Arriba.

In the same category of special features are the two Plainview stones whose complementary faces, although completely fused over, fit together perfectly.

The field program early revealed a frequent association of meteorites with ancient Indian ruins and campsites. Therefore, meteorites with established *archeological relations* are featured: Camp Verde, Winona, Livingston, hammer stones from Xiquipilco, an Indian axe from New Mexico, and the Horse Creek iron from an Indian campsite in Colorado.

Having collected four of the eight large individual aerolites (over 600 pounds weight) that have been discovered on the earth, we have re-

tained two of these in the collection, Hugoton and Morland, the latter being owned jointly with the estate of the late Dean M. Gillespie.

Probably no other collection contains the principal masses of so large a number of falls; the main portions of 141 falls are preserved in this collection.

Legal and Ethical Aspects

One of the problems that had plagued collectors of meteorites was the matter of legal ownership. The only laws covering meteorite titles had grown out of lawsuits between the finders of meteorites and the owners of the land on which finds had been made. The first court case arose many years before our time. There was no statute governing meteorites as such. The court decided that a meteorite belonged to the land on which it had fallen. Thus a precedent was established. In a later suit where the meteorite in litigation had not been seen to fall, the court decided it belonged to the land on which it had been found. In neither of these cases was any consideration given to the finder.

In all of our dealings and contacts with finders of meteorites and land owners involved during our early years, we cannot remember a single instance where either the finder of meteorites or an owner of the land on which the find had been made professed to believe that the law as embodied in these precedents was fair or ethical. We were very sure that a more equitable arrangement would have been some sort of division of ownership between finder and land owner. And the peaceful manner in which we were able to handle several hundred cases without litigation between 1929 and 1948 seems to be a fine commentary on the basic fairness of the American farmer.

During those years we purchased several thousand specimens without a single complaint ever being filed in court. Only once was a lawyer employed and that was simply to have him exercise the power of attorney in the purchase of a specimen in his own town, which was too far from our base to make our presence practicable.

Our plan was to act according to the law in all purchases, but where the find had been made by other than the land owner we always recommended a division of the sale price between the finder and the land owner. Usually, the land owner insisted on the finder receiving all of the proceeds but in a few cases the money was divided. In cases where the amount was small the transaction was merely verbal before witnesses. Where considerable money was involved a bill of sale was required, and this, of course, always had to come from the land owner in order to be legal.

It was always a matter of great pride that we could return to the same neighborhood year after year and be accepted in good friendship by those with whom we dealt.

Risks and Losses

Our method of searching for meteorites was a very expensive one. The lecture program involved travel expense often amounting to hun-

dreds of dollars a month. We had large printing and postage bills, chemical analyses costs, and the expense of a cutting laboratory. We had a far larger investment in a given meteorite than either the finder or legal owner of the specimen under consideration. In fact, ours was usually the only real investment involved, yet the find was not our property. We had to run the risk of losing it in case the other parties chose to push their advantage. There were a few cases when this was done and we lost the fruit of our labors, but as a rule persons involved felt an obligation to us for making the find possible. And since we followed the practice of paying the fairly well-established price of about one dollar per pound, we usually were at least given the right of refusal on any offer. There were, however, quite a number of specimens for the finding of which we clearly had been responsible, that went to various other institutions and collectors. Generally, these purchasers were not definitely aware of our part in the find.

We recognized early that this procedure, without legal protection for our heavy investment, was a risky business, but it seemed the only alternative would have been to forego the program entirely. And we had great faith that the method was yielding far more than meteorites—that it was proving a source of important information for the science of geology and astronomy. Consequently, we chose to continue in spite of risk.

One other scientist was pursuing a similar program. O. E. Monnig had come to us in 1934 and inquired if our method was secret. We told him it was not and explained it, merely requesting proper respect for prior work in any community. Within a year he too was recovering meteorites and some years later publicly gave us credit for the procedures employed. During the past decade he has recovered a large quantity of meteoritic material from old recorded falls and has also discovered a number of previously unknown falls. His work has been, and is, of great value to the science of meteoritics. We consider it a mark of highest integrity on his part that we and he have continued to work side by side in many areas, down to the present writing, without anything remotely approaching a serious conflict.

Financing

Shortage of funds was always a chief handicap in the prosecution of this field program. In order to make the venture self-supporting we supplied portions of our finds to various museums and collectors. Upon auditing our accounts over a period of years we were shocked to learn how expensive our various finds had been. The average cost of discovery ran about twelve to fourteen dollars per pound in addition to the purchase price paid to finders. This gave us a basis on which to determine prices to be charged for specimens.

Since we were working independently of any institution (except by honorary curatorship) it was also necessary for us to work out a plan to care for our retirement. We decided that a well-rounded collection

of meteorites would constitute an adequate savings account and found that by charging the customary dealer's prices for specimens or even somewhat less, we could usually retain half of a find and still realize enough to cover the cost of discovery and acquiring title. Supplementing this by a paid lecture tour once a year, the sale of literature, etc., we managed to break almost even most of the time.

Worlds in Collision*

By CECILIA PAYNE-GAPOSCHKIN

We are giving greater prominence to this analysis of "Worlds in Collision" than is usually accorded to book reviews. We feel that this procedure is justified for two reasons. 1. This book has been brought to the attention of a large reading public by having been mentioned favorably in several popular magazines. 2. The analysis here given is by a recognized authority in the field of astronomy, the science with which the book comes into closest contact, or sharpest conflict. EDITOR.

An Analysis

"Worlds in Collision" is an amazing book. Its author believes that a synthesis and distillation of comparative mythology *prove* that catastrophic changes have taken place in the Solar System during the past four millennia. His idea, that the "facts" of mythology compel a revision of the fundamentals of astronomy, geology, biology, and historical chronology, can be shown to be preposterous. This article presents an analysis by one reader, based on the book itself. On the face of it, the time spent might seem to be wasted. But the scholar has a duty towards the right advancement of learning.

1. On the Literary Sources

Lysander: It is not enough to speak, but to speak true.

Hippolyta: Indeed he hath played on his prologue like a child on a recorder, a sound, but not in government.

Theseus: His speech was like a tangled chain; nothing impaired, but all disordered.

A Midsummer Night's Dream, Act V, Scene i.

The framework of "Worlds in Collision" is built of comparative mythology and biblical history. The pages bristle with footnotes. Now a footnote may be used or abused; it may refer to a relevant passage, or it may be "merely corroborative detail intended to give artistic verisimilitude to a bald and unconvincing narrative" ("The Mikado," Act II, Modern Library Edition, p. 49; *cf.*, p. 56). One has but to look up

*Worlds in Collision, by Immanuel Velikovsky. (The Macmillan Co., 60 Fifth Ave., New York 11, N. Y.

the passage to find out which. Probably few readers will take this trouble. In so far as the books are contained in my library, I have done so. The results are far from convincing. "Corroborative detail, indeed! Corroborative fiddlestick!" (Loc. cit., p. 49).

When raw information is drawn from literary sources, the earliest record is obviously the most important. The words of Homer and Hesiod should carry more weight than the literary elegancies of Ovid, written perhaps 800 years later. The Biblical narrative is more weighty than the Rabbinical embroideries upon it. But it is characteristic of Mr. Velikovsky that he draws heavily on Ovid (43 B.C.-17 A.D.), Apollodorus (140 B.C.), the Midrashim and Haggadah, and the Early Fathers of the Church. One might as well turn to "Paradise Lost" for a factual account of the Creation. The more primitive sources lend his ideas little weight. Oddly enough he does not quote the anti-clerical Lucretius, or that mine of astronomical lore, Dante Alighieri.

Much is made of Typhon (Typhoeus), and it is worth while to examine his place in classical mythology. He was not a *"celestial monster"* (p. 173), but a giant, the son of Terra and Tartarus (earth and the underworld), a very earthly creature who survived long enough to beget Geryon, Orthos, and Cerberus. He is mentioned in the Iliad. We find him in the "Theogony" of Hesiod (c. 800 B.C.): "Huge Earth bare her youngest child Typhoeus of the love of Tartarus with the aid of golden Aphrodite" (821-822). An account of his combat with Jupiter follows. Ovid (Metamorphoses, Bk. II, Fables 2 and 3) describes his origin and his fate: "Typhoeus, *sent forth from the lower realms of earth,* had struck terror into the inhabitants of heaven, and . . . they all turned their backs in flight until the land of Egypt had received them. . . Typhoeus came there too and Jupiter . . . becomes the leader of the flock, whence even at the present day the Libyan Ammon is figured with horns. . . The vast island of Trinacria (Sicily) keeps down Typhoeus, that dared to hope for the abodes of heaven. . . He indeed struggles, and attempts often to rise, but his right hand is placed beneath the Ausonian Pelorus (Capo di Faro), his left under the Pachinus (Capo Perraro), his legs are pressed down by Lillyboeum (Capo Marsala), Aetna bears down his head; under it Typhoeus, on his back, casts forth sand and vomits flame from his raging mouth. . ." He is evidently a personification of volcanic action.

Other writers, however, placed Typhoeus elsewhere. The earliest record (Iliad, II, 783) says "Arimeia, where Typhoon has, they say, his resting place"; probably in Cilicia (How and Wells, a Commentary on Herodotus, Vol. 1, p. 257). Velikovsky informs us (p. 81) that "according to Herodotus, the final act of the fight between Zeus and Typhon took place at Lake Serbon," and refers us to Herodotus, III, 5. What does the Father of History actually say? On turning to the passage, we find: "At this lake, where, as was reported, Typhon was concealed, Egypt commences." The Greek word is the ordinary one for

"hidden"; nothing is said about Zeus or a battle. Velikovsky adds: "If Typhon lies on the botton of the sea, is he not the Pharaoh?", and suggests the welding together of two legends. The comment of How and Wells is relevant here (Vol. 1, p. 161): "This lake (now dry) lay parallel to the sea on the east side of Egypt. It was much feared for its swampy shores, which were said to be covered with drifted sand, and so to engulf the unwary. . . The army of Darius Ochus in 350 B.C. was said to have perished thus."

The whole structure of identifying the "celestial visitor" with the mythological Typhon or Typhoeus reposes on the statement in Pliny's "Natural History" about "a terrible comet . . . to which Typhon, the king of that period, gave his name." Mr. Velikovsky promises a revision of chronology that will identify Typhon with the last king of the Middle Kingdom. Until his arguments carry conviction, the estimate of the end of the Middle Kingdom in 1788 B.C. (Pfeiffer, Encyclopedia of World History) will remain acceptable. Such a figure is inconsistent with Velikovsky's date for the comet, which he naively takes from Hevelius (the year of the world 2453, or 1495 B.C.). This supposititious date of creation, 3948 B.C. (given by Hevelius in 1668, not in 1688, as Velikovsky states) is suspiciously near to the now discredited estimate of Archbishop Ussher (4004 B.C.) made in 1650. It will be seen that the "facts" have been judiciously weeded to suit the thesis, and that an early and legendary chronology is preferred to the results of modern scholarship.

Another point about Typhon deserves mention. Pallas appears as one of the giants, son of Tartarus and Terra (also parents of Typhoeus). He was killed by Minerva, who covered herself with his skin, whence, as some believe, she is called Pallas. But Cicero (de Natura Deorum) mentions *five* Minervas: a fifth, daughter of Pallas, put her father to death because he attempted her virtue. Cicero, at least, did not say that she was Minerva that sprang from Jupiter's head. In identifying Pallas with Typhon, and seeing here a description of an occasion when "the head of the comet and its tail leaped against each other" (p. 168), Velikovsky commits himself at least to a double paternity for Athena, if not to a double personality.

Mr. Velikovsky associates the Typhoeus of Greek legend with the Typhon of Egyptian mythology. This Typhon was (it is true) the illegitimate son of Earth and Heaven—one of quintuplets. His sisters were Isis and Nephthys, his brothers Osiris and Horus. He was the bad brother who compassed the death of Osiris by his guile. One can hardly read an invading comet into his machinations.

Let us turn to the myth of Phaethon. His name is derived from the defective Greek verb "to shine," and simply means "the shining one," not "the blazing star" (p. 159). He was the son of Phoebus (Apollo) and Clymene. He is best known from the beautiful late fable of Ovid, an embroidery on an earlier tale in the style of the age. Our author in-

forms us that "The earliest writer who refers to the transformation of Phaethon into a planet is Hesiod" (p. 160). What does the passage (Theogony, 989ff) say? It refers to a Phaethon that was the son of Cephalus and Eos, and son-in-law of Erechtheus, king of Athens, "whom when he was a young boy . . . laughter-loving Aphrodite seized and caught up and made a temple attendant by night, a divine spirit." That is all; it is to stretch the passage intolerably to see in it that he was turned into the *morning star*. Probably the meaning simply is that a signal honor was done to the king's son-in-law. Plato, four hundred years later, has the allegory in the "Timaeus;" Apollonius Rhodius retells it with changes a century later in connection with the Argonauts, and places the fall of Phaethon in the River Eridanus (the Po).

The "purple waves" are mentioned in the Homeric Hymn to Minerva, and Mr. Velikovsky makes something of it. But Homer habitually calls the sea "wine-dark, wine-colored" (*e.g.*, Odyssey, II, 421). And perhaps it is not amiss in this connection to quote two passages from "The Golden Bough" that relate to the myth and ritual of Adonis. "The Phoenician festival appears to have been a vernal one, for its date was determined by the discoloration of the river Adonis. . . . At (the spring) season the red earth washed down from the mountains by the rain tinges the water of the river, and even the sea, for a great way with a blood-red hue, and the crimson stain was believed to be the blood of Adonis, annually wounded to death by the boar on Mount Lebanon" (abridged edition, p. 336). "So year by year the Syrian damsels lamented his untimely fate, while the red anemone, his flower, bloomed among the cedars of Lebanon, and the river ran red to the sea" (loc. cit., p. 329). There are far more reasonable interpretations than "meteoric rust" for reddened waters.

Mr. Velikovsky evidently thinks that the epic of Gilgamesh refers to events contemporary with the Exodus. But it is well known that this famous poem is "older than the Hebrew by at least eleven or twelve centuries" (Frazer, Folk Lore in the Old Testament, abridged edition, p. 63). The "Hebrew account" is, of course, that of the Noachian Deluge, which Mr. Velikovsky places much earlier than the Exodus, and reserves for a *bonne bouche* in a later volume.

Some readers may not possess the works of Homer and Hesiod, Apollonius Rhodius and Lucian; but everybody has a Bible. The biblical references, when consulted, are little more convincing. We read (p. 230) that the army of Sennacherib was destroyed by fire from Heaven ("Ignis a Coelo" sounds more grandiloquent). But the three passages in the Scripture refer only to "the angel of the Lord." On looking into the matter we find the source of the heavenly fire in the earlier passage where Isaiah prophesies: "Behold I will send a blast upon him, and he shall hear a rumor, and shall return to his own land." It is disingenuous to distort this phophecy into an account of a subse-

quent event. And even so, the Biblical "blast" is not a "blast of fire"; the Hebrew word means "wind" or "spirit."

Other features of the same story are also distorted. We learn that Isaiah, apparently a skilled computer of planetary perturbations, mentioned "fifteen years of grace . . . (which) may also have had some relation to the periodicity of the catastrophes." What do the scriptural words actually say? "In those days was Hezekiah sick unto death. And Isaiah . . . said unto him: Thus saith the Lord, Set thy house in order, for thou shalt die, and not live. . . . And Hezekiah wept sore. Then came the word of the Lord to Isaiah saying, Go and say to Hezekiah . . . I have heard thy prayer, I have seen thy tears, behold I will add unto thy days *fifteen years* . . . for Isaiah had said, Let them take a lump of figs, and lay it for a plaster upon the boil, and he shall recover" (Isaiah, xxxviii, 1, 3, 4, 5, 21). In other words, as Mr. Velikovsky implies in another passage, Hezekiah fell sick of bubonic plague and was cured by Isaiah. The fifteen years were a personal matter concerning Hezekiah, not connected with cosmic phenomena.

We learn further that Hezekiah was obliged to reform the calendar owing to "the natural changes in the terrestrial rotation which took place in the days of Uzziah and again in the day of the burial of Ahaz." Mr. Velikovsky's references to the latter event are regrettably vague, and there is nothing in the scriptural passages that suggests anything beyond the fact that Ahaz died and was buried. "The adjustment of the calendar was a long and tedious process," says Mr. Velikovsky. What are the actual words of the Bible? "And Ahaz . . . shut up the doors of the house of the Lord, and he made him altars in every corner of Jerusalem. . . And Ahaz slept with his fathers . . . Hezekiah his son reigned in his stead. . . He in the first year of his reign, in the first month, opened the doors of the house of the Lord, and repaired them." There seems to be nothing here about a reform of the calendar.

The author of "Worlds in Collision" makes much of the darkening of the sun, of winds, earthquakes and fire, as factual descriptions of cosmic catastrophes. Two very famous passages seem to be omitted; one wonders why. "And behold, the Lord passed by, and a great and strong wind rent the mountains, and brake in pieces the rocks before the Lord; but the Lord was not in the wind; and after the wind an earthquake; but the Lord was not in the earthquake; and after the earthquake a fire; but the Lord was not in the fire; and after the fire a still, small voice" (I Kings xix, 11, 12). This is one of the great passages of literature; can it be that the chronology could not be made to fit?

The other passage, written by an orthodox Jew, is as follows: "Now from the sixth hour there was darkness over all the earth until the ninth hour . . . and the earth did quake, and the rocks were rent . . ." (Matt. xxvii, 45, 51). Luke (xxiii, 44, 45) adds a detail: "And it was now about the sixth hour, and a darkenss came over the whole earth

until the ninth hour, the sun being eclipsed." These features of the story of the Crucifixion were very likely inserted to lend solemnity to the narrative (the nearest eclipse, in 29 A.D., took place on November 24, nowhere near the time of the Passover). They carry at least as much conviction as the passages from which our author deduces cosmic catastrophes.

One more biblical reference, and I have done: an excellent instance of oriental hyperbole, partially quoted by Velikovsky as fact: "For, which is most to be wondered at, the fire had more force in the water, which quencheth all things: for the world fighteth for the righteous. . . But snow and ice endured the fire, and melted not." (Wisdom of Sol., xvi, 17, 22). "That is, hot ice and wondrous strange snow" (Midsummer Night's Dream, Act V, Scene i).

I will summarize my impression of the literary and biblical references that Mr. Velikovsky has furnished. They are selected with bias, rearranged *ad libitum*, and often misinterpreted. It is notorious that anything can be found in the Bible; the same is true of classical literature. In addition, the argument is so incoherently presented that nothing short of a card catalogue would suffice to align it in sequence—I will not say in logical order. Comparative mythology cannot be made to yield facts acceptable to physical science. "He who carries his story into the invisible world passes out of the range of criticism" (Herodotus).

2. The Scientific Arguments

Hyppolyta: This is the silliest stuff that ever I heard.

A Midsummer Night's Dream, Act V, Scene i.

I now turn to the "scientific" part of the book's argument. A work can scarcely be dignified by the name of science that displays ignorance of the scientific method and inability to handle the scientific vocabulary. The statement that "each planet is impelled by a motive force to proceed in a direction away from the sun" is of Aristotelian vintage. The zenith (unlike the ecliptic) is not fixed in space—it depends on the observer's latitude (p. 259). It is meaningless to say that "the pole (of Uranus) enters the tropics."

Errors of information are more serious than misuse of terminology. No comet has ever been observed to enter the solar system in a hyperbolic orbit (*i.e.*, from outer space); the modern theory of the origin of comets (J. H. Oort) interprets them satisfactorily as permanent members of the solar system. It is incorrect that "the probability that matter in explosion may reach a speed of 384 miles per second is very questionable"; speeds five times as great are observed on exploding stars. The "stones" that are part of a comet are not "dispersed in the neck and tail" (p. 43); they *constitute* its head. The tail, as far as we know, is completely gaseous. Venus is not brightest when nearest to the earth (p. 165). A planet does not show "emission lines of the sun" in its spectrum (p. 365); reflected sunlight has of course an absorption

spectrum. It is not true that "the absorption lines of the hydrocarbon spectrum lie far in the infra-red, where usual photographs do not reach." The best known of the hydrocarbon bands (the so-called G band given by the radical CH) is in the very middle of the photographed spectrum, is conspicuous in the spectra of many stars, and visible in all but the hottest. Hydrocarbon bands (from methane, CH_4) pervade the whole photographed spectrum of Jupiter, Saturn, Uranus, and Neptune—even one of the moons of Saturn shows them. The spectrum of CH_2 is shown by some cool stars. The hydrocarbon spectrum is the most commonly observed molecular spectrum in the whole astronomical material.

Even errors of information could be excused if the thesis of the book were reasonable. But the conclusions that Mr. Velikovsky draws are utterly impossible. A mystic may say, "Credo quia impossible"; a scientist cannot. We believe—and everything that we have learned has strengthened our belief—that the universe is consistent. The consistency has been confirmed by every forward step. The Ptolemaic model placed the earth at the center of the solar system, with planets carried on "wheels within wheels." Copernicus visualised the sun at the center of circular planetary orbits, and interpreted the non-uniformity of motion by a slight displacement of the orbits so that the sun was not at the center. Kepler took the further step of realising that the orbits are elliptical with the sun at one focus. It was Newton who proved (what others had already guessed without proof) that a central force, varying inversely with the square of the distance, would produce this effect, and was the only type of force that would do so. Remaining irregularities of motion led (on assuming the inverse square law to be rigorous) to the deducton that a hitherto unknown planet (Neptune) existed, and to its accurate location in space. An additional refinement by the theory of relativity showed that the unexplained part of the rotation of the orbit of Mercury could largely be accounted for.

An even more severe test of the consistency of the laws of motion is furnished by the moon. With exquisite precision, the "lunar theory" recognises 155 major periodic terms in the moon's longitude, over 500 smaller ones, and about half as many in the moon's latitude. No astronomer doubts that the remaining unexplained small terms in the moon's motion will fall within the domain of previously consistent rules. The number of known facts (resting on accurate measurement) that form the grounds for our "belief" in the validity of the laws of motion is almost beyond imagination.

But now we are asked to believe that "facts," selected (with bias and readjustment) from comparative mythology compel us to revise the laws of celestial mechanics, and to admit erratic motions of the principal planets within historic times. We are asked to believe that Venus was shot out from Jupiter and in 1495 B.C. practically made a direct hit on the earth, retreated, returned within about six weeks, took herself off

again, and scored another bullseye after 52 years. She then (we are asked to believe) encountered Mars, who (despite his lightweight standing) propelled her into her present orbit, and proceeded to make two hits (or near-hits) on the earth on his own account, fifteen years apart, before retiring to his present orbit. If I read Mr. Velikovsky aright, he hopes to link the earlier Noachian Deluge with similar antics on the part of Jupiter. We have here an extraordinary achievement in a very difficult type of marksmanship—four (or even five) hits in a couple of thousand years, and all (by a lucky chance) at crucial points in the history of Israel. It is not only impossible. It is ridiculous.

The first encounter with Venus, we are told, either stopped the earth's rotation or swung its axis over, apparently a complete somersault—the author does not seem to be very sure which. But the earth, a gigantic, massive flywheel with vast rotational energy, could only be stopped or tipped by direct impacts; and direct impact would certainly have disrupted the earth and exterminated every living thing for good. (Our author's vaguely expressed idea that electrical or magnetic forces could do the trick is quite untenable, as a brief calculation will show). Let any doubting reader convince himself, by stopping or turning over a rapidly spinning bicycle wheel, that angular momentum is a brute fact of nature. The larger and heavier the flywheel, the greater the momentum. A stoppage of the earth, that would make the sun appear to stand still, simply could not happen.

Not content with stopping the earth, Mr. Velikovsky will have it start up once more in a few days. Another force, equal to the stopping force, must now be applied in the opposite direction. He calls in the sun's (very doubtfully real) magnetic field, oblivious of the fact that if the earth could be started up by this means, (which it could not), it would be accelerated in the same way, and would go on spinning faster and faster. The days would be getting shorter all the time, which obviously they are not. The "forces" of nature cannot be switched on and off at will.

I will pass over the "meteorites that remained suspended in the celestial sphere" (whatever that means) "for about fifty years," to fall in the nick of time in the days of Joshua. I will pass over the mention of the picture in which "Sirius appears west of Orion instead of east" (p. 108)—apparently the heavens were not only turned upside-down, but also inside-out, if this passage is taken at its face value. But the deposit that was brought by the tail of the comet calls for more than passing mention. We are to believe that petroleum fell first, and then the "carbohydrates precipitated" as manna; and flies, apparently carried from Jupiter, invaded the earth. Now the tails of comets show the spectra of sodium, carbon, nitrogen, the hydrocarbon radical CH, cyanogen, and carbon monoxide (strong poisons, these two). Several comets have enveloped the earth with their tails in recent times, without depositing either petroleum or manna, or indeed producing any noticeable effects.

Showers of soap and alcohol would have been just as probable as manna and gasoline; all are equally preposterous, if only because the necessary hydrogen is lacking. If petroleum is "star oil," how did it come to be associated with such comparatively low-lying strata that it must be reached by drilling? And how did the flies adjust themselves from the low-temperature atmosphere of Jupiter (hydrogen, methane, ammonia) to the temperate envelope of the earth (oxygen and nitrogen)? They must have had amazing physiological versatility.

There were several changes, Mr. Velikovsky assures us, in the length of the day and of the month, as well as in the distance of the earth from the sun (and thus in the year) prior to 747 B.C. The climate of the earth would of course have been greatly affected by these changes, whereas there is evidence that there have been no over-all climatic changes since 2000 B.C. at least. And a 36-day month would have thrown all eclipses (retrospectively) off schedule, incidentally making total eclipses of the sun impossible. But solar eclipses, conforming to the regular motions of the sun-earth-moon system as we know them today, can be traced back at least to 1062 B.C., so that variations of the day, month, and year such as our author contemplates cannot possibly have occurred.

The astronomical conclusions reached by Dr. Velikovsky are untenable and absurd. From the points of view of geology, biology, and historical chronology the same can certainly be shown, but it is beyond my province to show it. I should like to conclude with a word on a much-publicised aspect of the book—its impact on religious thought.

"Worlds in Collision" is a mixture of bad "science" and (in so far as it deals with scripture) a new reading of some of the Bible that is far from the "literal interpretation" of the Fundamentalists. To see in it, as Mr. Oursler does in the "Readers' Digest," a step towards unification of Science and Religion, is to do great disservice to both. Neither Science nor Religion can feel any gratification.

What I would say was better said, sixty-five years ago, by Thomas Huxley in "Science and Hebrew Tradition" (1885):

"The antagonism of Science is not to religion, but to the heathen survivals and the bad philosophy under which religion herself is often well nigh crushed. And, for my part, I trust that this antagonism will never cease; but that to the end of time, true science will continue to fulfill one of her most beneficient functions, that of relieving men from the burden of false science which is imposed upon them in the name of religion."

HARVARD COLLEGE OBSERVATORY.

Some Notes on the Astronomical Method of Studying Bird Migration

By WILLIAM A. RENSE

Introduction

The astronomical method of studying bird migration has been discussed by the writer in a previous paper.[1] In the past two years, mainly because of the efforts of Dr. George H. Lowery, Jr., Director of the Museum at Louisiana State University, a rather extensive application of the method has been made[2,3]. The results have proved to be of great interest and importance to ornithologists and have caused considerable attention to be focused on the new method. In collaboration with Lowery and his associate, Robert J. Newman, the writer has extended the theory in the original paper and herewith presents a summary of the new work together with a few examples from actual bird observations to illustrate the use of the fundamental equations.

In the astronomical method an observer makes telescopic observations of birds crossing the lunar disc during the migratory season, and records the path (with respect to horizontal and vertical axes) of each bird that crosses the disc. From such data (under the assumption that the birds are flying horizontally) one can, with the help of information taken from an ephemeris of the moon, compute the directions of flight. The heights of the birds may be found by the method of parallax[1] provided two observers make simultaneous observations through telescopes separated by a few feet. The directions and heights being known, one can then calculate the so-called flight density in any given direction; namely, the number of birds per hour that pass over an imaginary line one mile long on the earth's surface, the line being perpendicular to the direction of flight. The two fundamental equations are:

$$\tan\ (\eta\text{-}\psi_0) = \cos Z_0 \tan\theta \qquad (1)$$

$$\rho = 5280\ N/L, \qquad (2)$$

where η is the average azimuth of the direction of flight of the birds, ρ the flight density, and N is the number of birds observed per hour. The significance of the other symbols is given in the first paper.[1] The directional equation, (1), is here written in its accurate form, involving no approximations, and is superior to the one presented in the original article.

A large number of observations have been made by amateur astronomers and others who have cooperated with Lowery[3] in studying the spring migration of 1948. The analysis of these results has fully justified the use of the astronomical method and has pointed the way to an extension of the method.

The Third Fundamental Equation

In attempting to use equation (2) one usually found that no parallax

measurements were available to give the height of the bird so that the quantity L was an unknown factor. A statistical way of avoiding this difficulty was eventually developed, however, after it was discovered from the parallax measurements which were available that birds rarely fly more than 5000 feet high and that on any given night there are birds that fly at widely varying elevations. If one makes the assumption, therefore, that birds fly at random heights from about a mile downward, a formula for computing flight density may readily be obtained. This assumption is of course subject to alteration by future results, but as an approach to the statistical problem of obtaining flight densities when parallaxes are not known, it is of great help. The new formula is mathematically correct for the full moon, but densities computed from it may be subject to error if the birds in question do not fly at random heights from a mile downward.

The new equation may be obtained from a study of Figure 1. The

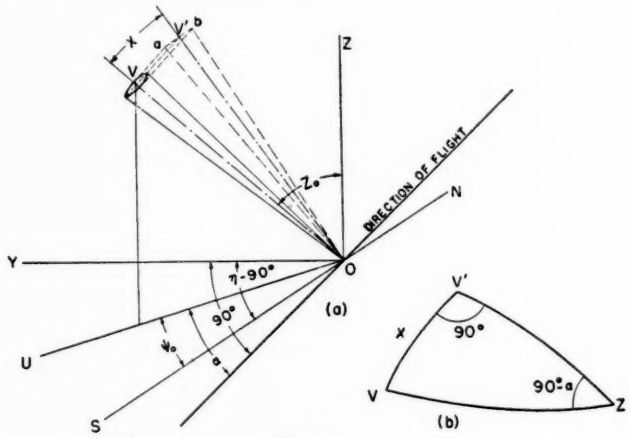

FIG. 1

Projection of the cone of vision on a plane perpendicular to the line of flight of the birds.

plane marked YOZ is a vertical plane perpendicular to the direction of the migrating birds which pass through the indicated mile-high cone of observation with vertex at O. SN is a south-north line on the surface of the earth and UOV a vertical plane through the center line, OV, of the cone. The azimuth (reckoned westward from the south point) of the latter plane is ψ_0, the zenith angle of the cone is Z_0, the azimuth of the direction of flight is η, and the angle between line UO and the direction of flight is a. The line VV′ is drawn perpendicular to the vertical plane YOZ and meets it at V′. The lines OV′, OV, and OZ, where Z is the zenith point, form a spherical triangle on the celestial sphere as

shown in Figure 1, b. The area of the triangle formed when the cone is projected on plane YOZ may now easily be found. With sufficient accuracy the projected area is equal to (ab) (OV) cos χ, or, making use of the law of sines for a spherical triangle and the fact that line ab is the diameter of the cone at a mile height, we can express the area in square miles as

$$0.009\sqrt{1-\cos^2\alpha\sin^2 Z_o}/2\cos^2 Z_o.$$

If N is the number of birds seen per hour then, since all these birds pass through the projected area, the number of birds per hour cutting through a plane one mile on a side perpendicular to the earth's surface and to the direction of flight is N divided by the above area. But this is nothing more than ρ, the regular flight density, because all the birds are assumed to extend only up to one mile. Thus:

$$\rho = \frac{220\,N\cos^2 Z_o}{\sqrt{1-\cos^2\alpha\sin^2 Z_o}};\quad \alpha = 180^\circ - \eta + \psi_o \qquad (3)$$

η being the azimuth of the direction of flight, ψ_o the azimuth of the moon, Z_o the zenith distance of the moon, and N the number of birds observed per hour traveling in the direction η. Equation (3), which holds only for full moon since no phase correction was included, may be referred to as the third fundamental equation. To allow for phase, one may use equation (2), and find L by a graphical method,[1] assuming an average height of half a mile for the birds.

Flight Densities

Since different birds may be migrating simultaneously in different directions, then at any given time at a fixed station several flight densities corresponding to the various directions are often needed to describe the observations. For example, 8,000 birds/mile/hour may be moving due north and 1,000 birds/mile/hour to the northwest. Two densities are thus needed. In general, however, birds do not move in exactly one or two different directions, but often have been found to migrate in a fan-shaped way, with the trend north (in spring) or south (in autumn). Part of this spread is undoubtedly real, part is due to the ever present errors of observation. In order to facilitate the reduction of data on spring migrations, the directions have been given by naming sectors, as in Fig. 2, a. All birds flying within a given sector are added in finding the corresponding flight density for that sector, and their directions are stated as that of the center of the sector. Sector density vectors for a typical station are shown in Fig. 2, b.

Dealing with the sector densities as vectors, we can obtain the components of each along the N-S and E-W lines and obtain four vectors which we call hourly flight displacements in the N, W, E, and S directions, respectively. The hourly N-flight displacement gives the number

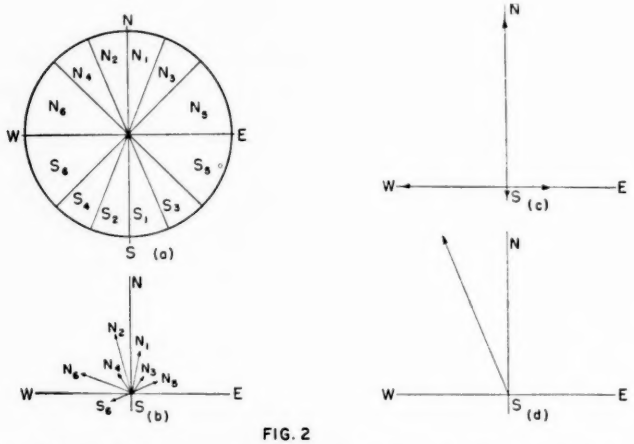

FIG. 2

(a) Division of the compass directions into sectors. (b) Examples of sector density vectors for a typical station. (c) Hourly displacement vectors deduced from (b). (d) Hourly flow vector obtained from (c).

of birds per hour displaced from south to north across a line drawn due east and west one mile long on the earth's surface; the hourly E-flight displacement gives the number of birds per hour displaced from west to east across a line drawn due north and south one mile long on the earth's surface, etc. It is to be remembered that the crossing of the line by the birds is here not confined to a perpendicular crossing, but to any oblique crossing as well—just so it is from one side to the other. Hourly displacement vectors are shown in Fig. 2, c.

The resultant of the four hourly displacement vectors is called the hourly flow vector (Fig. 2, d.). It is a measure of the net exchange of birds over the station, its direction being such that a maximum number of birds are displaced across a mile-long line drawn on the earth's surface perpendicular to this direction. It is understood that birds traveling in opposite directions neutralize each other as far as net displacement is concerned. Thus, if, of all the birds flying, half are flying due east and half due west, then the net displacement at the station is zero. When the hourly flow vectors for a given time at a sufficient number of stations are known, it is possible to learn something of the pattern in which the birds are moving over a wide region; the hourly flow vectors aid in picturing the lines of flight or "flow" like the "stream lines" of hydrodynamics. The component of the hourly flow vector along any line is the net displacement per hour in the direction of that line. It is of course a maximum along the hourly flow vector itself.

One other notion is of importance in describing bird migration with data taken by the astronomical method. It concerns itself with the *degree* of migration at a station for a given interval of time. Intuitive

ideas of the degree of migration are such that none of the densities or vectors discussed so far is an adequate measure of it. The hourly flow vector does not meet the intuitive requirements because, as pointed out before, it may be zero even though there are a lot of birds migrating overhead. A scalar quantity may be found, however, which meets the requirements quite well. This number is obtained by merely adding, arithmetically, the magnitudes of all the sector densities for the given interval. The number gives an estimate of the total number of birds per hour participating in migration *regardless of their direction of flight*, and is defined as migration activity. An easy way of looking at it is this: imagine a circle one mile in diameter drawn on the earth's surface, center at the station; the total number of migratory birds crossing over this circle in unit time is the migration activity.

When average hourly flow vectors for all the hours of an entire night are combined they give what can be called the nightly flow vector. Similarly, a nightly sector density may be found by adding the average hourly densities for a given sector for all the hours of the night. Some examples of nightly sector densities and nightly flow vectors are shown in Fig. 3. These are for several stations on the night of April 23-24,

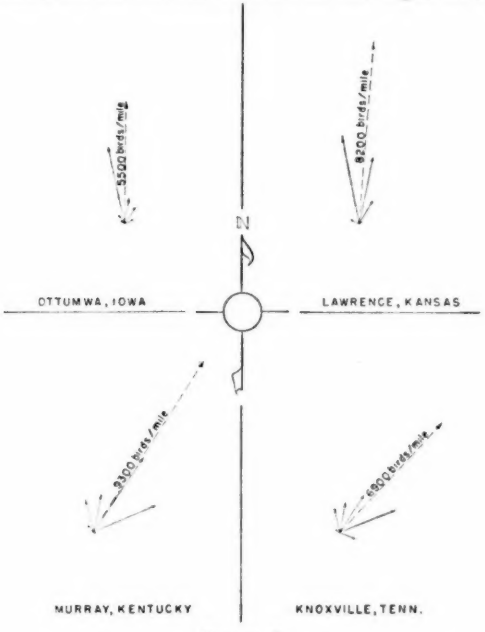

FIGURE 3

Examples of nightly sector densities for four stations on the night of April 23-24, 1948. The nightly flow vector is shown in each case by a dotted arrow and its magnitude in birds/mile is indicated.

1948. The data are taken from observations submitted by various observers to Dr. Lowery.[3] The nightly flow vectors are shown as dotted lines. If the latter, along with other values obtained for the same night, are plotted on a map of North America, as in Fig. 4, one can easily

FIGURE 4

Nightly flow vectors for ten stations on the night of April 23-24, 1948. Ottumwa (O), Iowa; Louisville (Lo), Kentucky; Lawrence (La), Kansas; Knoxville (K), Tennessee; Murray (Mu), Kentucky; Stillwater (S), Oklahoma; Mansfield (Ma), Louisiana; Winter Park (W), Florida; Tampico (T), Mexico; Progreso (P), Mexico. Reference to Figure 3 will enable one to estimate the scale of the vectors.

observe the trend of migration in the eastern half of the United States and Mexico for that particular night. Note the evidence for trans-Gulf migration as suggested by the nightly flow vector at Progreso, Mexico, on the Yucatan peninsula. The large magnitude at Tampico points to considerable coastwise migration as well. The general northward trend of the migration, and the fanning out of the birds over the nation as they come up the Mississippi valley is also suggested. Of course it is not to be thought that these inferences are any more than possibilities; one such set of data proves little. But Lowery has examined and analyzed similar sets of data for the spring migrations of 1945 to 1949, and has arrived at several important conclusions which now seem fairly well established. The reader is referred to Lowery's paper[3] for details. A few of his results may be mentioned here: 1. Night migrants fly

singly more than in flocks. 2. Night migration characteristically begins with twilight, gradually increases in intensity to a maximum near midnight and falls off as dawn approaches. 3. A strong correlation exists between weather conditions and the direction and intensity of flights of birds (for example, migration is often relatively intense on the western side of high pressure areas). 4. Frontal disturbances may precipitate large number of migrants thus locally increasing ground densities of birds.

The writer and a graduate student, Charles Arney, had the privilege during early April in 1949 of being guests of the U. S. Navy on a Gulf training cruise. Our aim was to make telescopic observations of the moon with the hope of helping to establish or disprove trans-Gulf migration by obtaining actual flight densities in the middle of the Gulf. Amateur astronomers who are veterans of the Navy will sympathize with us in our efforts to observe birds crossing the lunar disc while we were perched on the deck of a fast-moving destroyer. The image of the moon as seen through our 20-power scope wandered about in a fashion that was decidedly encouraging to dizziness. We did succeed in getting continuous observations over several night periods from Key West across the Gulf to Tampico.

With one notable exception virtually no birds were seen through the telescope during each of the two clear nights spent on the Gulf between Key West and Tampico. The only place at which flight densities were observed which were comparable to those found on a typical land station in the United States was about a hundred miles directly off the Yucatan coast. All the birds were sighted by Mr. Arney for about an hour and a half period around midnight, while the ship was moving nearly parallel to the coast. The birds were larger than average. However, smaller birds may easily have escaped observation because of the difficulties caused by the movements of the ship. Even so, a flight density of the order of 500 birds/mile/hour has been computed. The birds were flying north-northwest on the average; no birds were flying in a southerly direction. Though this is good direct evidence for trans-Gulf migration, it is not absolute proof. Until analysis of the data is complete, and until many similar sets of data from ships and islands in the middle of the Gulf are obtained, no convincing conclusions can be made. It might be mentioned that the above data support the inferences made from observed heavy densities[2,3] at Progreso, Yucatan (See Fig. 4). Two nights after the above observations were made the writer and Mr. Arney, at Tampico, Mexico, found very heavy flight densities, nearly ten times that in the Gulf off Yucatan. Certainly, then, there is also considerable coastwise migration, as is well known.

Of the relative amounts of coastwise and trans-Gulf migration little can be decided at present, for there are so many other factors to be taken into account—the magnitude of daytime migration, the heights at which birds fly over the Gulf, the difficulties inherent in mid-Gulf ob-

servations, etc. (If the reader thinks that this problem is a trivial one to ornithologists, he should read Lowery's paper[2] as well as one by Williams[4]).

Limitations of the Astronomical Method

The success of the astronomical method depends upon the happy fact that many birds at night do not migrate in concentrated flocks; consequently they are spread out over a wide horizontal area and can be rather faithfully sampled by the small cone of observation presented to an observer looking at the moon through a telescope. Birds generally fly low enough to be resolved and seen as birds (except for large zenith angles) and high enough to be within the range of good focus. Only rarely can even an experienced ornithologist identify a bird from its moving silhouette against the moon.

The data, being of a statistical nature, are reliable only when accumulated in great quantity over a period of many seasons and at well-distributed stations. Errors in observation, variations between observers using different instruments in their abilities to detect birds, errors in reductions, presence of non-migrant birds, over-simplifying assumptions in the theory, failure to distinguish between species of birds, and many other difficulties stand in the way of the ready acceptance of many of the conclusions that might follow from an application of the astronomical method. The start that has been made shows great promise, however, and it is hoped that more observations will be forthcoming.

The writer is grateful to Dr. George Lowery and Mr. Robert Newman for the keen interest they have shown in pursuing and applying the astronomical method and for their many contributions in all aspects of the work. The writer and Mr. Charles Arney also wish to express their gratitude to the U. S. Navy for the privilege of being guests aboard the *USS Wallace L. Lind* during a training cruise in the Gulf. In particular we are indebted to Captain J. L. Woodbury, USN, Commander Destroyer Squadron SIXTEEN; Captain C. B. Laning, USN, Commander Destroyer Division 162; Commander J. C. Ford, USN, District Public Information Officer, Eighth Naval District; Commander R. E. Wheeler, USN, Commanding Officer, *USS W. L. Lind,* and to the other officers and men of the *Wallace Lind* for their interest and cooperation in regard to our problem.

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University of Colorado, Boulder, Colorado.

The Planets in July and August, 1950

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. Although these are the two months of greatest heat in the northern hemisphere, the earth will be at aphelion, that is, farthest from the sun, on July 5. By the end of August the sun will be only 8 degrees north of the equator.

Moon. The phases of the moon will occur as follows:

Last Quarter	July	6	9 P.M.
New Moon		14	11 P.M.
First Quarter		22	5 A.M.
Full Moon		28	10 P.M.
Last Quarter	August	5	2 P.M.
New Moon		13	11 A.M.
First Quarter		20	10 A.M.
Full Moon		27	9 A.M.

The moon will be at perigee on July 25 and August 19.

Evening and Morning Stars. Saturn and Mars will be best seen in the southwest just after dark, and Jupiter will rise later in the evening. Venus will be conspicuous in the east before dawn.

Mercury. Mercury will be more than 27 degrees east of the sun on August 21, so it should be easy to find in the western twilight during the last three weeks of that month. On August 16 it will be 3 degrees south of Saturn, which it will outshine by a whole magnitude.

Venus. During July Venus will be a most conspicuous object, rising before 3 A.M., but by the end of August the favorability of its placement will have diminished so that it will be rising after 4 A.M.

Mars. Mars will move rapidly during this period from the region of γ Virginis to a point just west of α Librae at the end of August. By this time it will have faded so as to be scarcely brighter than its so-called rival, Antares.

Jupiter. Jupiter will be rising earlier every evening, so that on August 26 it will stand in opposition to the sun and be visible all night. On July 31 at 3 A.M. the moon will be passing less than a degree south of Jupiter.

Saturn. Early evenings of July will present the last really favorable opportunities to view this planet with its now-elusive ring system.

Uranus. Uranus will be moving east-southeastward in a region about midway between ϵ and μ Geminorum.

Neptune. Neptune will be moving slowly southeastward at a half-degree south of 44 Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
May 6, 1950.

Asteroid Notes

By HUGH S. RICE

For early summer observation of minor planets we have four rather bright asteroids; and the background of stars, star clusters, and nebulae is a fertile field for telescopic investigation.

7 IRIS appears in the Milky Way in Sagittarius, north of the milk dipper. The opposition date is July 1, the predicted magnitude 8.9.

The apparent path of 419 AURELIA is 2 or 3 degrees north of that of IRIS; the opposition time is July 2, and the magnitude 9.3. These magnitudes are supposedly photographic, and the visual magnitudes are usually ½ to more than 1 unit brighter.

25 PHOCAEA is mostly in Sagitta, the opposition is July 13, and the "mag" 9.0. Just before the ephemeris begins, the planet is placed right in the arrow configuration of the constellation, which fact is very easily determined by reference to a small-scale atlas (such as Norton's) whose equinox is 1950. Such reference to a small-scale chart is only for preliminary orientation; for a good plotting of the path, a large-scale chart is used, in order to distinguish the asteroid immediately from the surrounding faint stars not found on the small-scale atlas. The well-known Beyer-Graff chart appears to have been reprinted rather recently; it was not available for a number of years. (The small-scale *Schurig's Himmels-Atlas*, however, is not available any more, and recent reports state it will not be, in the future.)

15 EUNOMIA is in eastern Sagittarius, and at opposition July 16, at 8.5 mag. In the region where IRIS and PHOCAEA are, there are many excellent Messier objects for observation with small and other telescopes. In fact this field and the area north of it are excessively rich in interesting celestial objects and always well repay extensive examination.

ASTEROID EPHEMERIDES

0^h U.T. Equinox 1950

7 IRIS

1950	α h m	δ ° ′
June 8	19 2.1	−20 32
18	18 53.7	−20 21
28	18 43.5	−20 10
July 8	18 32.7	−20 0
18	18 22.3	−19 50
28	18 13.6	−19 42

419 AURELIA

1950	α h m	δ ° ′
June 8	18 58.4	−17 44
18	18 52.8	−17 13
28	18 45.2	−16 52
July 8	18 37.0	−16 40
18	18 29.8	−16 36
28	18 25.4	−16 39

25 PHOCAEA

1950	α h m	δ ° ′
June 18	19 39.6	+18 4
28	19 35.3	+20 44
July 8	19 28.9	+22 35
18	19 21.5	+23 26
28	19 14.8	+23 15
Aug. 7	19 10.0	+22 8

15 EUNOMIA

1950	α h m	δ ° ′
June 18	20 7.8	−22 17
28	20 0.8	−21 58
July 8	19 51.6	−21 39
18	19 41.1	−21 18
28	19 30.6	−20 55
Aug. 7	19 21.3	−20 30

Hayden Planetarium, American Museum of Natural History, New York, 1950 May 21.

Occultation Predictions for July and August, 1950

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1950	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
	OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′									
July 2	χ Capr	5.3	6 48.1	—1.4	+1.0	44	8 4.0	—1.8	—0.1	257
4	70 Aqar	6.2	5 8.0	—0.9	+2.1	39	6 17.8	—1.5	+1.3	259
31	50 Aqar	5.9	2 16.0	—0.8	+1.7	80	3 22.1	—1.0	+1.8	226
Aug. 1	317 B.Aqar	6.3	8 37.4	—1.5	+0.4	61	9 52.0	—0.8	+0.7	219
7	27 Taur	3.8	4 46.2	+0.9	+2.1	20	5 22.6	—0.3	+0.8	297
7	BD+23°563	6.1	4 45.2	+0.1	+0.9	115	5 22.7	+0.8	+2.2	202
7	BD+24°599	6.4	8 52.4	..	..	125	9 29.7	..	..	182
17	50 Virg	6.2	23 35.3	—1.0	—1.5	107	0 40.2	—0.6	—2.0	312
20	4 Scor	5.6	22 41.7	..	..	173	23 18.1	..	..	229
21	π Scor	3.0	0 2.5	—1.9	—0.3	75	1 11.0	—1.6	—1.6	314
22	*W* Sgtr	4.7	23 5.4	—1.6	+0.7	96	0 25.0	—1.9	+0.2	271
23	183 B.Sgtr	6.2	22 22.9	—0.7	+0.6	122	23 22.8	—1.7	+1.5	234
25	χ Capr	5.3	23 54.4	—1.2	+2.0	44	1 0.1	—1.4	+1.0	277
26	φ Capr	5.4	4 8.5	—2.2	—0.2	92	5 12.2	—0.6	+1.0	203
	OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′									
July 2	χ Capr	5.3	6 17.9	—1.4	+1.9	31	7 24.5	—2.2	+0.3	280
2	φ Capr	5.4	10 40.1	—2.7	—2.1	115	11 18.6	+0.7	+2.2	180
4	70 Aqar	6.2	4 50.3	—0.5	+2.2	41	5 51.2	—0.8	+1.4	267
21	*f* Virg	5.9	2 7.2	—1.0	—1.6	114	3 13.2	—0.6	—2.0	310
31	182 B.Aqar	6.2	5 22.4	—2.1	+0.9	103	6 14.7	—0.7	+2.4	189
Aug. 1	317 B.Aqar	6.3	8 9.5	—1.1	+1.7	31	9 27.0	—1.8	+0.5	246
4	π Pisc	5.6	10 6.3	—1.8	+1.4	60	11 30.9	—1.4	+1.7	219
7	BD+24°599	6.4	8 22.5	—0.7	+1.4	92	9 22.6	—0.2	+2.5	216
20	π Scor	3.0	23 24.5	—2.0	+0.2	96	0 42.7	—1.7	—0.9	306
26	φ Capr	5.4	3 29.9	—1.9	+1.1	71	4 49.8	—1.6	+0.9	231
	OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +31° 0′									
July 2	χ Capr	5.3	5 49.0	—1.6	+2.1	46	7 3.8	—2.1	+0.6	271
2	φ Capr	5.4	10 41.3	..	..	135	10 55.3	..	..	155
10	66 Arie	6.1	11 0.2	+0.4	+3.0	18	11 56.2	—2.0	+0.5	280
21	*f* Virg	5.9	2 15.8	—1.1	—1.9	134	3 24.2	—0.9	—1.7	294
31	182 B.Aqar	6.2	5 4.5	—2.0	+0.2	115	5 44.1	—0.6	+3.5	180
Aug. 1	317 B.Aqar	6.3	7 43.5	—1.3	+2.2	33	9 5.8	—2.1	+1.1	241
4	π Pisc	5.6	9 39.2	—2.1	+1.7	67	11 1.8	—1.2	+2.5	208
7	BD+21°599	6.4	8 8.6	—0.5	+0.9	99	9 0.2	+0.3	+2.5	209
20	π Scor	3.0	23 13.0	—1.6	—0.4	124	0 34.8	—2.2	—0.4	285
26	φ Capr	5.4	3 6.5	—2.0	+1.2	79	4 27.0	—1.8	+1.5	226

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

July 2		ϕ Capr	5.4	9	34.8	−2.0	+1.0	66	10	56.9	−1.6	+0.8	232
11		χ Taur	5.5	12	11.3	−0.6	+1.3	92	13	11.2	−0.1	+2.3	221
21		f Virg	5.9	1	42.2	−0.8	−2.2	162	2	47.6	−2.0	−1.2	279
30	152	B.Capr	6.5	12	18.5	−1.4	−1.0	88	13	14.6	+0.1	+1.0	203
31	182	B.Aqar	6.2	4	47.0	−0.4	+1.1	103	5	38.2	−0.8	+2.4	207
Aug. 1	337	B.Aqar	6.4	14	0.5	−1.3	−0.9	85	15	0.3	−0.2	+1.3	203
2	80	B.Pisc	6.3	6	24.6	−0.8	+0.6	116	6	56.6	0.0	+3.3	177
4		π Pisc	5.6	9	30.6	0.0	+2.8	15	10	31.8	−2.0	+1.0	269
7	BD+24°599		6.4	8	16.2	+0.5	+1.5	63	9	12.1	+0.1	+1.4	252
9	406	B.Taur	5.6	11	26.9	−1.7	−0.8	138	11	58.3	+1.1	+4.0	197
20		π Scor	3.0	22	53.7	0.0	−0.9	156	23	48.0	−2.0	+1.2	257
24	234	B.Sgtr	5.9	6	13.8	−2.1	−0.4	89	7	27.6	−1.0	+0.2	231
26		ϕ Capr	5.4	2	42.7	−1.0	+1.6	73	3	55.2	−1.4	+1.4	248

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

Some Characteristic Features of the Sikhota-Alin [Ussuri§] Iron-Meteorite Shower [of the U.S.S.R.: ECN = ∓ 1347,462]*

E. L. KRINOV

(Presented by Academician S. I. Vavilov on the 22nd of November, 1947)

Translated, with Critical Commentaries,† by

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On the 12th of February, 1947, about 10:35 A.M., local legal time, in the Maritime Province, at a point whose geographic coördinates are $\phi = 49° 10'$ [46° 9′.6] [N.], $\lambda = 104° 19'$ east (from Pulkova) [134° 39′.7 E. of Greenwich], there fell a

§The name *Ussuri* should continue to be used to designate the meteorites that fell on 1947 February 12 for the following reasons: (1) Since the time of Brezina, meteorites have been named for a *place* of importance as near the place of fall of the meteorites as possible; Ussuri is such a place, and, in fact, was first used by the Russians to designate the fall in question; (2) the name *Sikhota-Alin*, later substituted for *Ussuri*, is objectionable not only because it is a longer hyphenated word, but, primarily, because it has already been pre-empted to refer either to the very extensive Sikhota-Alin mountain range (as on recent definitive maps published by the National Geographic Society) or to the even larger geographic unit of which this range is the central topographic feature; (3) the *place name Sikhote-Alinsk*, introduced by Dr. Walter Grigaitis in the translation he prepared for Dr. Charles P. Olivier (*P. A.*, **58**, 129-32, 1950), cannot be justified; no town with this name is located near the Ussuri strewn field; (4) the place Novopoltavka, which, according to V. G. Fesenkov, is "the nearest inhabited point" to the strewn field, can scarcely be construed as "a place of importance" in the sense of Brezina; certainly it is less important than Ussuri.

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†Words, symbols, and critical commentaries inserted by the translators have been inclosed in brackets [ ].

heavy metal-meteorite shower, accompanied by very spectacular ocular and acoustical phenomena.[1] The working up of the data collected by the author during the expedition of the Committee on Meteorites of the Academy of Sciences of the U.S.S.R. (27th April to 17th May, 1947), and the investigation of some specimens of meteorites, permit us to establish the following characteristic features of the Ussuri meteorite shower.‡

In the first place, one must observe that the Ussuri fall represents a unique iron-meteorite shower on the Earth, observed during its fall and at the same time the most massive fall of meteoritic iron.[2]

The study locally of the circumstances of the fall of this meteoritic shower permits us to determine the ellipse of dispersion [strewn field] and to clarify a series of peculiarities in its structure. First, attention is directed to the comparatively small area of the ellipse: 7 to 8 square km., with the length of the major axis about 5 km., directed with its north end (or tail) along an azimuth of 344° from north towards east [*i.e.*, the direction of motion along the major axis was from N. 16° W. to S. 16° E.] (Fig. 1).‖ It should be observed, however, that a completely reliable determination has been made of only the western side and the southern side (or head side); the eastern and northern boundaries of the ellipse have been determined only tentatively.

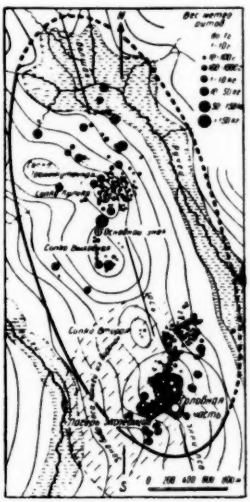

FIG. 1

A map of the ellipse of dispersion. *Black circles* indicate the locations where individual specimens were found; *light circles*, the largest of the funnels, of diameter greater than 10 meters; the *shaded zone*, the most pronounced destruction of the forest.

‡At the present time, the author is continuing further studies of all collected materials, consisting of descriptions of the meteorites and of investigations of their internal structure.

‖[Fig. 1 is reproduced in *P. A.*, **58**, 131, 1950.]

The second characteristic of the ellipse of dispersion is [its] deviation from the usual regularity in the distribution of meteoritic masses in relation to their sizes. The whole area of the ellipse is sharply divided into 2 parts: the head part, of area approximately 0.75 square km., where the greater masses fell, and the tail part, [which is] considerably larger in area. In the head part, 106 funnels of diameters from 0.6 to 28 meters were discovered, whereas 21 funnels of diameters larger than 10 meters were discovered, and 18 funnels, of diameters from 3 to 10 meters, were located. The funnels are distributed at random, and frequently a small one is found next to a large one or on its boundary. A study of the structure of the funnels has shown that they differ sharply from known meteoritic craters. The circumstances of the fall have been described in detail by the Academician V. G. Fesenkov.[3]

In the funnels and between them were collected numerous meteoritic fragments [ranging] in weight from a fraction of a gram up to tens of kilograms. These resemble in their external appearance the fragments from the meteoritic craters at Canyon Diablo, [Arizona,] U.S.A., and at Henbury, [Central] Australia, and also individual specimens of the meteoritic group, Chinghe [Chinga], (U.S.S.R.). In the majority of cases, the fragments have a compressed, armor-like, sometimes *S*-shaped or flat form, with torn, sharp ends and often with long, thin, bent projections. In the fractures of large fragments separate projecting pieces of octahedral form usually are seen, as well as the general octahedral structure. On the convex surfaces of particularly large fragments it is possible to observe traces of and sometimes even rather well-defined regmaglypts [*i.e.*, piezoglyphs]. As a rule, the fragments are covered with rust and layers of clay; frequently, bunched lawrencite sweat-drops also are observed, whereas, on the predominantly concave surfaces, the presence of an intensely blue and even a rainbow-like coloration is found. A characteristic peculiarity of the fragments is found also in the clear evidence of deformation from impact against hard rocks—in the form of scars, striations, deep cracks, *&c.* (Fig. 2) [Krinov's Fig. 2 is reproduced in the lower left-hand corner of Fig. 2 in *P. A.*, **58**, 132, 1950]. With the aid of a hand magnet, it was possible to extract out of the mixture of clay and pieces of porphyry, in the funnels and around them, the smallest magnetic [meteoritic] particles.

During the excavation of 2 funnels, of diameter 0.6 meter, whole individual meteorites, weighing from 68.7 to 84.8 kg., were extracted. In larger funnels, of diameter from 2.6 to 2.8 meters, were found meteorites weighing about 300 kg. each. In one case, a meteorite had numerous cracks; in another, it was fractured into 4 large pieces that we were able to fit together along the lines of fracture, [thus] restoring the original shape. The partial opening of a large funnel, 23 meters in diameter, led to the discovery, under a 0.5 to 1-meter thick layer of fragments, of a deposit of whole [*i.e.*, unfractured] layers of porphyry; no large meteoritic mass was found there, however; only numerous small meteoritic fragments mixed with fragments of porphyry and with clay were collected. Measurements from the bottoms of the funnels, of the directions of the breaking of the trees caused by the impact against them of meteoritic masses, gave as the mean of 18 cases the result: azimuth = 359°, angle (from the normal) = 30°.

In the tail part of the ellipse were collected 257 whole individual specimens weighing from a fraction of a gram to 300 kg. The smallest of the individual specimens found weighed 0.18 gm., and has dimensions of $3 \times 4 \times 5$ mm.; this represents apparently the smallest iron meteorite in the world. Specimens weighing up to 2 kg. were found lying on top of the forest carpet, and only in rare

cases were they discovered [to be]partially buried in the soil. Larger specimens were lying in small depressions (lune-shaped pits), some completely open and some partly or completely filled with a layer of earth. In some cases the meteorites were found near the lune-shaped pits formed by their impact. In a number of cases tree tops were observed to have been cut off by meteorites. Measure-

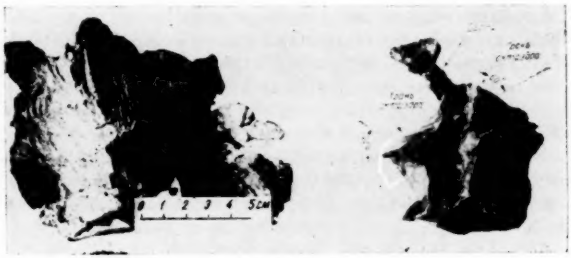

FIG. 2 [Left-hand fig.]

A typical meteoritic fragment with characteristic torn edges and sharp lines of striation (on the concave surface).

FIG. 3 [Right-hand fig.]

A complete-individual specimen covered with a fusion crust and having sharply defined regmaglypts [piezoglyphs]. The structure is easily visible, as well as separate faces.

ments of the directions to the breaks from the places of fall of meteorites gave, on the average (7 cases): [an] azimuth of 357°, and [an] angle from the vertical of 27°. The distribution of individual specimens in the ellipse shows a marked concentration at 2 points. Some specimens were discovered even in the head part of the ellipse.

Individual specimens are characterized by sharply defined regmaglypts, by sculpture, and by the presence of a fusion crust of a steel-blue color sometimes having a violet shade. In the majority of cases, these specimens have an irregular form of fracture and a peculiar macrograin structure, not yet observed, at least in such sharply pronounced form, in any other iron meteorite. [Of previously studied meteorites, Central Missouri, Missouri, and New Baltimore, Somerset County, Pennsylvania, have structures most closely approaching that exhibited by the Ussuri irons.] Often it was possible to observe separate macrograins projecting out; usually, these either are placed parallel to each other or intersect at an angle of 60°. Not infrequently flat surfaces of triangular form with equal angles are observed, representing evidently the faces of an octahedron, along which, in part, the fracture of the meteoritic mass took place in the air. Intersecting among themselves, these form the same dihedral angles of 60° (Fig. 3) [this figure is reproduced in the lower right-hand corner of Fig. 2 in *P.A.*, **58**, 132, 1950]. Especially remarkable is the presence, on many flat surfaces, of some examples of clearly marked Widmanstätten figures, accompanied by the corresponding orientation of separate regmaglypts, projecting macrograins, and their edges. Such cases have been observed, in general, for the first time. Another characteristic peculiarity of individual specimens is a pronounced melting [even] up to the formation of deep worm-like "gutters" and fissures, caused undoubtedly by the [former] presence in the meteorite of numerous large inclusions of troilite, [a mineral] often observed [both] on the surface of specimens and on cut sections.

The presence on many specimens of a fusion crust of the second kind [*i.e.*, a secondary fusion crust], sometimes in a merely initial form, also is remarkable, and, in connection with this crust, of regmaglypts in various stages of development. Many specimens show definite elements of orientation, if, on the front surfaces, the crust has a wavy or wrinkled structure, [thus] presenting a peculiar picture. On the rear surfaces the crust is porous, whereas, on the sides, sharply defined swellings, forming the usual wreath [lateral edge], are observed. On many specimens even of small size, numerous fractures and scars from impacts against rocky strata or individual stones are seen; not infrequently spots are observed where pieces, evidently projections, have been broken off.

Investigation of the internal structure showed that the present meteorites belong to the [subclass of] coarsest octahedrites¶ of the [same] type [as] Sandia Mountains [New Mexico], [while the percentage composition indicated in the footnote¶ does not differ significantly from that obtained by analysis of the Sandia Mountains, New Mexico, meteorite, nevertheless, as Stuart H. Perry has pointed out, the Sandia Mountains meteorite is a *granular hexahedrite* (cl. = H,a), and not a *coarsest octahedrite* (Ogg), as Krinov asserts; both the descriptions and the photographs of the Ussuri meteorites published by Krinov and others show that these siderites, like Sandia Mountains, are granular hexahedrites and not coarsest octahedrites] and Santa Luzia [de Goyaz, Goyaz, Brazil].[4]

By macroetching, separate large macrograins and rounded or polygonal flat surfaces were made evident. These structural components either are found in contact with one another or are separated by layers of troilite, which sometimes reach considerable size, forming large inclusions. In smaller amounts, mainly in contact with troilite, schreibersite is found. The meteoritic material in its mineralogical composition represents in the main a single component, kamacite. The picture on the etched surface, just described, appears as a result of the formation, during etching, of the usual oriented luster. Consequently, as a result of the position of an etched surface relative to the source of illumination, some structural components become light and others dark, whereas, in a different position, a reversed picture is obtained (Fig. 4) [Krinov's Fig. 4 is reproduced in the upper row of Fig. 2 in *P.A.*, **58**, 132, 1950]. Thru etching, extremely numerous Neumann

FIG. 4

Etched surfaces of cut samples: *A*. A complete-individual sample. The interior structure and large inclusions of troilite (on the left) are seen. On the right and below, *B*. A sample cut in two. The strongly deformed internal structure is seen.

¶To this structure corresponds exactly the chemical composition of the present meteoritic material: Fe, 94%; Ni, 5.5%; Co, 0.38%; *D.A.N.* [*Doklady Akademii Nauk*], **53**, No. 3.

lines also are brought out; furthermore, several systems are observed simultaneously. Macroetching of the fragments of specimens shows the same structure; a pronounced deformation of the latter [the Neumann lines], caused evidently by the impact of the meteoritic mass in its fall, is, however, observed.

In conclusion, the following inferences can be drawn. The meteoritic shower was formed as a result of [the] breaking up in the Earth's atmosphere of an initially large, single mass. This breaking up occurred near the region of retardation, which was situated relatively low above the Earth's surface, [at an altitude] of the order of several kilometers. Large meteoritic masses, reaching the surface of the Earth with high velocities, in direct relation to their sizes, and accompanied by air waves, shattered rocky strata, forming funnels, and broke up into numerous fragments [ranging in size] down to the minutest particles. It is possible to establish an approximate [lower] limit of 300 kg. for meteorites [that are] preserved from breaking up in their fall. There was no explosion, in the sense of a sudden transition of a solid meteoritic mass into [the] gaseous state. It is possible to reach this conclusion also on the basis of [the] absence of any earthquake [such as resulted from the impact of the Podkamennaya Tunguska, Siberia, meteorites of 1908 June 30]. Plastic deformations observed on some fragments were caused, evidently, by a transient local heating up to a temperature of several hundred degrees at the moment of impact and break-up of the meteoritic masses. The macrograin structure facilitated the extensive break-up of the initial meteoritic mass in the air and the subsequent shattering of large meteoritic masses on impact against rocky strata. At the same time, the viscosity and the high malleability of the meteoritic iron assisted in [the] formation of meteoritic fragments of deformed shape. As far as [it is] possible to judge from the circumstances of the fall, the total mass of meteoritic material that reached the surface of the Earth amounted to approximately a hundred tons. The expedition collected only about 5 tons, including 1.777 tons of individual specimens.

Committee on Meteorites,
Academy of Sciences, U.S.S.R.

Received 3 November, 1947

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Notice of the 13th Meeting of the Society

The 13th Meeting of the Meteoritical Society will be held on Tuesday, Wednesday, and Thursday, September 5, 6, and 7, 1950, at the Museum of Northern Arizona, Flagstaff, Arizona, and at the Canyon Diablo Meteorite Crater. The scientific sessions will open at 9 A.M. and 2 P.M. on Tuesday and Wednesday at the Museum of Northern Arizona; an excursion to the nearby Canyon Diablo Crater is scheduled for Thursday.

Members of the Society are hereby requested to send the Secretary, at their earliest convenience, the titles and abstracts (the latter in form for publication in *C.M.S.*) of any papers that they may wish to present, or to have presented, at the meeting, of which all the scientific sessions will be open to the public and at which guests, as well as members, will be welcome.

Inasmuch as the 13th Meeting will be an electoral meeting, the attention of members is hereby directed to Art. 3, Sect. 3, of the Constitution of the Society (*C.S.R.M.*, **2**, 323-4, 1941) concerning the nomination of candidates for election.

In accordance with Art. 3, Sect. 5, of the Constitution (*loc. cit.*, p. 324), the Council has determined that 3 Vice-Presidents and that both a Secretary and a Treasurer shall be elected for the 1950-54 term.

JOHN A. RUSSELL, *Secretary*

Elections to Fellowship

The following members of the Meteoritical Society were elected by the Council to fellowship in the Society as of date 1950 April 15:

Professor George Baker, Melbourne University, Carlton, N. 3, Victoria, Australia

Brandon Barringer, The Curtis Publishing Co., Philadelphia 5, Pennsylvania

D. Moreau Barringer, Jr., 1528 Walnut St., Philadelphia 2, Pennsylvania

Richard Barringer, Radnor, Pennsylvania

Carl A. Bauer, University of Michigan, Ann Arbor, Michigan

Dr. Carl W. Beck, University of New Mexico, Albuquerque, New Mexico

Dr. Harrison Brown, University of Chicago, Chicago 37, Illinois

Dr. Robert S. Dietz, United States Naval Electronics Laboratory, San Diego 52, California

Dr. Curvin H. Gingrich, Carleton College, Northfield, Minnesota

Walter H. Haas, University of New Mexico, Albuquerque, New Mexico

Edward P. Henderson, United States National Museum, Washington, D. C.

Dr. Helmut E. Landsberg, Shreve Rd., R.F.D. 1, Falls Church, Virginia

Dr. John T. Lonsdale, University of Texas, Austin, Texas

Dr. Roy K. Marshall, University of North Carolina, Chapel Hill, North Carolina

George J. Neuerburg, 12615 Chandler Av., North Hollywood, California

Professor Richard M. Pearl, Colorado College, Colorado Springs, Colorado

Dr. John S. Rinehart, 309 A Saratoga Av., China Lake, California

Dr. John A. Russell, University of Southern California, Los Angeles 7, California

Walter W. Zimmerman, 20032 Parthenia St., Northridge, California

JOHN A. RUSSELL, *Secretary*

A Symposium on Meteorites, May 2, 1950

A symposium on meteorites was held on May 2, 1950, as a part of the program of the 26th Annual Meeting of the American Association for the Advancement of Science, Southwestern Division, Flagstaff and Grand Canyon, Arizona, April 30-May 4, 1950. Four (4) of the 6 papers of the symposium were contributed by representatives of the University of New Mexico, Albuquerque, and 2 by a representative of the American Meteorite Museum, Winslow, Arizona. The roster of the papers reads as follows:

1. "The Barringer (Canyon Diablo, Arizona) and Odessa, Texas, Meteorite Craters," Lincoln LaPaz, University of New Mexico.

2. "The Meteorite-Crater Problem in the Light of Recent Explorations," H. H. Nininger, American Meteorite Museum.

3. "Hardness Tests on Meteoritic Constituents," H. H. Nininger, American Meteorite Museum.

4. "The Odessa, Texas, Meteorite," Carl W. Beck and Lincoln LaPaz, University of New Mexico.

5. "The Breece, New Mexico, Meteorite," Louis H. Goldsmith and Carl W. Beck, University of New Mexico.

6. "The LaLande, New Mexico, Meteorite," Ralph G. Stevenson, Lincoln LaPaz, and Carl W. Beck, University of New Mexico.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

Spring Meeting of the A.A.V.S.O. The Physics Department of the Pennsylvania State College was host to the AAVSO at its annual Spring Meeting over the weekend of May 6, in the town of State College, Pennsylvania. Thanks to Dr. H. L. Yeagley and Mr. W. F. Mullen, everything was planned very expertly for the meeting. The members of Alpha Nu, the student astronomical society, took charge of registrations, and were enthusiastic guides and general information distributors.

Members began to gather at the Nittany Lion Inn on Friday afternoon. They came from New England, New York, New Jersey, Pennsylvania, Washington, and Ohio. We are glad to welcome our good observer, Alika Herring, of Middleton, Ohio, to the first meeting he has been able to attend.

The Council meeting got under way at 4 P.M., with its regular business and semi-annual reports from the various committees. The Nominating Committee presented the following slate for Council Members:

Mrs. Margaret Beardsley	Mrs. Helen S. Hogg
Robert M. Greenley	Walter L. Moore
Ferdinand Hartmann	Harold B. Webb

The Council accepted the report with thanks, and approved the ballot to be voted on at the Annual Meeting in October.

On Friday evening, the members were invited to a lecture by Dr. Yeagley on "Terrestrial and Extra-Terrestrial Influences on Bird Navigation." Dr. Yeagley is internationally known for his research into the mysteries of how birds navigate. He started his studies with a few pairs of homing pigeons, but later acquired large flocks of them, which he trained and tested in many ways. At present he is having a very interesting time with a family of wild ducks which have taken up their headquarters on a pond at the college.

After the lecture, the members of Alpha Nu took the visitors on tours to the telescope workshops, the College Planetarium, and the student observatories. Unfortunately the skies clouded over and there was no opportunity for observing the planets or favorite variables. But inspection of the beautiful equipment the Physics Department has in the Osmond Laboratory kept everyone occupied until a very late hour.

On Saturday morning, Mr. Mullen gave the official address of welcome to the Association from the College. The Technical Session followed, with these interesting papers presented by the members:

1. "Solar Photography with a Schott UG 2 Filter," Neal J. Heines.
2. "The AAVSO Observing Program," Margaret W. Mayall.
3. "Introductory Research in Astrophysics," William Tifft.
4. "High Temperature Industrial Use of Solar Energy," Willard F. Mullen.
5. "Variability of Fluctuations of o Ceti," Carlos Garcia Mata.
6. "Solar Faculae," H. B. Rumrill.
7. "Process of Faculae Photography," Dr. Ohman (Stockholm).
8. "A Discussion of Occultation Studies in England," Mrs. Hartness Beardsley.

The Solar Division is a very active branch of the AAVSO, and the papers on solar problems were of great interest. Mr. Heines reported on several methods of photographing the sun with filters. Mr. Mullen told of the extremely high temperatures that can be obtained from solar energy. He also mentioned the various experiments being carried out in heating houses by means of solar energy.

Mr. Garcia Mata, of the Foundation for the Study of Cycles, reported on his analysis of the variations of o Ceti. Mr. Campbell had collected for him a set of observations of the variable since the early 1800's. From his study of the 20th century observations, Mr. Garcia Mata found he could accurately predict the fluctuation that occurred in the 1800's. He determined a mean period of 331.405 days.

Margaret Mayall reported on several lists of variables for special programs which will be available soon. Among them are a photographic program, stars to be observed with photoelectric cells, some bright stars which need watching, and some special variables for those observers who want to keep watch on a small group of variables, night after night.

Mr. Tifft's excellent astrophysical paper was part of his winning entry in the Westinghouse Science Talent Search. He told of his research into the formation of spectral lines and the prediction of their intensities.

Notes on Some Variables

T Cas 001755. Had its usual still-stand during January and February, on the rising branch of the light curve.

RV Cas 004746a. A very narrow maximum (9.5 magnitude) about February 15. Rose from 13th magnitude January 15 and dropped back to 11th magnitude by March 5.

T Ori 053005a. Decrease in light of about a magnitude between April 6 and 16.

SU Tau 054319. Le Vaux calls attention to sudden irregularities, confirmed by other observers, and wonders if it indicates an approaching minimum.

SS Aur 060547. A narrow, but well-observed maximum occurred March 7.

SU UMa 080362. Maximum of 11.0 magnitude observed by Fernald on April 16.

Z UMa 115158. The accompanying light curve, compiled from the continuous plot on exhibit at the Spring Meeting, shows the activities of this star since 1928. After a long period of inactivity, it has again started to vary, with a range of about 2 magnitudes and a period of approximately 200 days.

Z URSAE MAJORIS, 115158, FROM 1928 TO 1950

Observations received during April: A total of 2,736 estimates was received during the month from 48 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	44	71	Kelly, F. J.	11	11
Ahnert	28	172	Knowles	25	68
Ancarani	25	52	de Kock	104	265
Blunck	2	2	Lankford	21	30
Bogard	59	143	Lee	24	59
Burkhead	1	1	Lowder	6	6
Cain	7	9	Luft	5	10
Charles	19	19	Melville	11	25
Cooke	4	6	Meyer	9	14
Cragg	21	21	Miller	9	9
Dafter	7	20	O'Byrne	12	20
Darnell	2	7	Oravec	70	306
Diedrich, D.	1	1	Parker	27	27
Diedrich, G.	2	4	Pearcy	50	51
Dillon	7	12	Peltier	108	152
Drakakis	16	51	Penhallow	40	80
Estremadoyro, G. A.	2	3	Pierson	28	28
Fernald	233	436	Rick	2	3
Ford	22	23	Rosebrugh	15	76
Galbraith	18	71	Stevens	12	15
Greenley	61	103	Tifft	5	5
Halbach	34	34	Venter	17	33
Hartmann	126	135	Yamada	12	26
Hiett	10	14	—		—
Holloway	7	7	48	(totals)	2,736

Nova Search. Reports on the Nova Search Program were received during April from 11 observers as follows:

Observer and Areas	Nights	Mag.	Observer and Areas	Nights	Mag.
Adams, 33 and 34	2	6	Diedrich, G., 56	5	6
Adams, 33 and 34	2	7	Drakakis, North Pole	1	6
Adams, 33 and 34	4	8	Luft, 33, 34, and 35	2	5
Adams, 53 and 54	2	6	Rick, Dome	3	1
Adams, 53 and 54	3	7	Rick, 65	1	3
Adams, 53 and 54	4	8	Rich, 65	2	5
Blunck, 8, 9, 10	6	6	Rosebrugh, Dome	2	2
Diedrich, D., 94	1	1	Rosebrugh, Dome	4	3
Diedrich, D., 94	4	3	Rosebrugh, 1	3	4
Diedrich, D., 94	1	4	Rosebrugh, 34	2	3
Diedrich, D., 94	6	5	Rosebrugh, 34	3	4
Diedrich, D., 94	4	6	Smith, F. W., 3 and 4	4	6
Diedrich, G., Dome	4	1	Wells, 69 to 72, 80 to 83	2	6
Diedrich, G., 56	3	1	Wells, 91 to 93, 101 to 103	2	6
Diedrich, G., 56	1	3	Wells, 110, 111, 121, to 123	2	6
Diedrich, G., 56	3	4	Yamada, 19	4	6.5
Diedrich, G., 56	4	5	Yamada, 57	1	6.5

May 15, 1950.

Comet Notes

By G. VAN BIESBROECK

So far 1950 is one of the quietest years that we have had as far as comets are concerned. None is known to be in reach of ordinary telescopes. PERIODIC COMET D'ARREST which comes to perihelion June 6 will probably be located in the

morning sky at this coming dark of the moon. Last month the recovery was announced by one on the strength of a pair of plates showing a very faint little spot, not brighter than 17th magnitude, which seemed to move in the proper direction between the two exposures. The images must have been spurious because longer exposures on subsequent nights failed to bring out the object. So the search should be continued. (The following note was added on May 13. PERIODIC COMET D'ARREST was definitely located on two plates taken this morning with the 82-inch reflector. It appears as a fuzzy spot of magnitude 16. The correction to Recht's ephemeris is only $+0^m5$ in right ascension and zero in declination, showing that the date of perihelion comes only some 3 hours earlier than the prediction. The comet was also recognized on plates taken here on April 20 when it was only an 18th magnitude diffuse spot. The object suspected on April 14 is spurious. Since the comet is expected to gain somewhat in brightness until July and its position is improving it will probably be followed for several months but it will remain beyond the reach of ordinary telescopes.)

Several formerly observed comets are in reach of larger telescopes such as the PERIODIC COMETS SCHWASSMANN-WACHMANN No. 1 and OTERMA 1942 VII, both of which are observed every year and followed around their orbits. In April the former one, which shows such striking variations in brightness, appeared practically stellar and as faint as 19th magnitude. The latter had its normal fuzzy appearance and brightness.

COMET JOHNSON (1949 *a*), while it is the brightest object now observable, is however considerably fainter than the 11th magnitude predicted by the computer. On April 14 I estimated the magnitude as 13.5. A tail about 5′ long followed the nucleus.

McDonald Observatory, Fort Davis (Texas), May 11, 1950.

General Notes

The readers of this journal may recall that there is no issue in July, the next scheduled issue being due on August 1. Last year the August issue was delayed because of the absence of the editor. The situation this year is quite similar to that of last year. The editor will be one of the visiting professors at the San Diego State College for the first part of the summer session. He will return to Northfield about August 5, and the August issue will be distributed about August 15. EDITOR.

Dr. Carl von Wiezsäcker, of the University of Chicago, gave a lecture on May 10 at Haverford College, Haverford, Pennsylvania, on the subject, "Evolution of External Galaxies."

Dr. Gerard P. Kuiper, professor of astronomy, Dr. Lester R. Dragstedt, chairman of the department of surgery, and Dr. Willard F. Libby, professor of chemistry in the Institute for Nuclear Studies, all of the University of Chicago, have recently been elected members of the National Academy of Sciences.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on May 12 in Randall Morgan Physics Laboratory, University of Penn-

sylvania. The speaker was Dr. Enos E. Witmer, Assistant Professor of Physics, University of Pennsylvania, his topic being "The Evolution of Relativity."

University of Durham Bi-Centenary of Thomas Wright of Durham

The University of Durham is planning to celebrate, on 2 June 1950, the 200th Anniversary of the publication in 1750 of Thomas Wright's "Original Theory of the Universe." This book gave, 35 years before Herschel, the correct explanation of the Milky Way and inspired Kant to develop his Theory of Celestial Evolution.

The Cleveland Astronomical Society

The annual dinner meeting of the Cleveland Astronomical Society was held on May 5, 1950. The 6:15 dinner was at a restaurant near the Warner and Swasey Observatory, after which the group adjourned to the Observatory to hear Dr. Roderic M. Scott, an alumnus of Case Institute of Technology and now with the Perkin-Elmer Corporation. His topic was "Post-war Astronomical Instruments." The address, which will be published in full in these pages, was well received by the capacity crowd of over 100 members and guests. Officers for the coming year were elected as follows:

President—Dr. J. J. Nassau	New Council Members:
1st Vice Pres.—Dr. David Dietz	Mrs. Wilbert J. Austin
2nd Vice Pres.—Mr. Warner Seely	Mr. Wells Knierim
Secy.-Treasurer—Mrs. Arthur Townhill	Mr. Stephen Lawson
Recording Secy.—Dr. H. F. Donner	Dr. Donald MacRae
Librarian—Miss Wunderlich	Mrs. S. K. Towson

PAUL ANNEAR, *Recording Secretary*

Burrell Memorial Observatory, Baldwin-Wallace College, Berea, Ohio.
May 12, 1950.

Provisional Sunspot Numbers for April, 1950*

1	72	11	88	21	85
2	80	12	91	22	70
3	122	13	95	23	96
4	133	14	80	24	128
5	136	15	100	25	138
6	139	16	126	26	142
7	151	17	128	27	119
8	114	18	77	28	160
9	120	19	88	29	153
10	109	20	100	30	154

Mean Value for April
R = 113.1

The mean definitive sunspot-numbers for 1949 by months are now available. They are:

Mo.	No.	Mo.	No.	Mo.	No.
Jan.	119.1	May	106.2	Sept.	145.3
Feb.	182.3	June	121.7	Oct.	131.6
Mar.	157.5	July	125.8	Nov.	143.5
Apr.	147.0	Aug.	123.8	Dec.	117.6

Yearly mean, 134.7.

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Popular Astronomy in a New Rôle

Popular Astronomy has entered into an agreement with University Microfilms, Ann Arbor, Mich., to make available to libraries material from Popular Astronomy in microfilm form. One of the most pressing problems facing all

types of libraries today is that of providing adequate space for a constant flood of publications. Periodicals pose an especially difficult problem because of their bulk and number. Microfilm makes it possible to produce and distribute copies of periodical literature on the basis of the entire volume in a single roll, in editions of 30 or more, at a cost approximately equal to the cost of binding the same material in a conventional library binding.

Under the plan, the library keeps the printed issues unbound and circulates them in that form for from two to three years, which corresponds to the period of greatest use. When the paper copies begin to wear out or are not called for frequently, they are disposed of and the microfilm is substituted.

Sales are restricted to those subscribing to the paper edition, and the film copy is only distributed at the end of the volume year.

The microfilm is in the form of positive microfilm, and is furnished on metal reels, suitably labeled. Inquiries concerning purchase should be directed to University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

Book Review

A Concise History of Astronomy, by Peter Doig. With a foreword by Sir Harold Spencer Jones. vi—320 pages. (No illus.) (London: Chapman & Hall, 1950. 21 shillings.)

The next step in a rounded astronomical education beyond the assimilation of the conventional background of facts, and the understanding of basic concepts, is reading something of the development of the science. This pleasant duty is now made the more enjoyable with the publication of Peter Doig's "A Concise History of Astronomy."

For all the lore in so distinguished a heritage, astronomy has been forty years without a new account in English covering all periods. In 1907 Bryant's history appeared and two years later Forbes' came out (followed by an unrevised edition in 1921). The latter had merits within too small a compass while the former had only greater readability to recommend it above the more authoritative work by Arthur Berry printed in 1898.

It is seen that we get back to the 19th century before encountering a standard work. The deficiency would have been more conspicuous but for a few biographies and the generous space devoted to astronomy in the general histories of science. Of course there was "A Hundred Years of Astronomy" by Waterfield, published in 1938. This however is close reading in the rise and fall of astrophysical theories rather than an over-all view.

The history of astronomy has, in practice, been politely considered a good thing but its study by the average reader of POPULAR ASTRONOMY has consisted largely of chance bits, some very sound and interesting contributions appearing in this journal. At most he is likely to have settled down for a few hours with that classic by Agnes Clerke, "A Popular History of Astronomy during the 19th Century," and read Newcomb's "Reminiscences," or Turner's "Astronomical Discovery."

The first half of the present century has seen substantial additions to our knowledge of early astronomy and the last fifty years themselves need chronicling in spite of the danger of short focus on the too recent past. In 320 pages Mr. Doig, editor of the esteemed *Journal of the British Astronomical Association,* has included brief modern estimates of the ancients with longer treatments of current problems.

Devoting 35% to the 20th century this book will distress the historian as out of balance but the purpose stated in the preface is "to provide in a concise manner but as comprehensively as possible, an up-to-date account of value to the general reader of the development of astronomy which will also be a handy reference book useful to students as a record of the main events and of the chief work of individuals." The bare quotation does injustice to the easy prose style in the body of the book. It is, however, the author's definition of what he proposed to do and in the main he succeeds.

Note the emphasis on the "development of the science" to its present state rather than the position of astronomy in various cultures. This is what the majority of readers with both amateur and professional interests seek. In answering questions on how our beliefs regarding the observable universe grew to their current acceptance, Mr. Doig has done a considerable service.

From William Herschel on, some 60% of the book, the treatment is so strictly topical that the work of individuals, observatories, "schools," and countries is submerged. It turns into as engaging an exposition of modern astronomical theories and their supporting evidence as there is to be had. By the inclusion of so much lucid explanation the general reader is catered to but the volume of history as such is reduced to rather modest proportions.

Looked at in one light "A Concise History" is really a treatise on astronomy as it was in 1949 with an expanded historical introduction. There is every reason to have such a book and the author can enjoy his royalties without its presence lessening the need for a history of more use to historians and a reference work of more use to astronomers.

Historians can still trace the later fortunes of theories discussed in the standard histories of astronomy while astronomers can remind themselves of classic papers by dipping into this volume. The former will, however, usually find the treatment too brief; the latter will be disturbed by the difficulty, in many cases, of identifying the year of publication in order to find easily the full reference in the *Jahresbericht*.

Pointing out who might be disappointed in the new history is hardly fair since those for whom it was chiefly written will be delighted. Nowhere else can one find between stiff covers such illuminating descriptions of the work of modern astronomers from Adams to Zwicky.

Whole sections like those on the sun with names of Menzel, Roberts, and Waldemeier cropping up give a countemporary touch that leads the reader right into the current literature. With a sound elementary course behind one, a Russell, Dugan, and Stewart at hand, Mr. Doig's book is a most rewarding introduction to an appreciation of what is happening on the frontier of the science. The makings of a perspective in which to view new papers in the journals could be thus secured with pleasure and profit.

Peter Doig wrote "An Outline of Stellar Astronomy" (1947) and he shows an equally full command of subject matter in his second book. He writes with a British-American approach that may pique some continental astronomers for in the later chapters few men are mentioned who have not written their principal papers in English. The heroes tend to be the Cambridge school of astrophysicists and the Californian telescopes, a common and innocent bias.

Scholars will still consult Ernst Zinner, "Die Geschichte der Sternkunde" (1931) but the number of people who will read "A Concise History of Astronomy" will be a gratification to its worthy author.

Vassar College, Poughkeepsie, N. Y. JOHN W. STREETER.